A LONGITUDINAL STUDY OF DEVELOPMENTAL CHANGES IN CHILDREN'S PROBLEM-SOLVING STRATEGIES BETWEEN 3 AND 9 YEARS

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ABSTRACT

Previous studies of children's use of problem-solving strategies have been cross-sectional, and narrowly defined. These have described age-related development across a wide range of cognitive competencies. Parallel with this child development literature, studies in both humans and animals have linked active reduction of error in problem-solving to inhibitory function of a mature and intact hippocampus, and also to the frontal lobes.

The present study was designed to investigate the development of availability and use of strategies by children in problem-solving tasks, and whether development of inhibitory ability is the underlying and enabling process for this.

96 children aged 3 years (N=32), 5 years (N=32), and 7 years (N=32), fully representative of sex and socio-economic status, were each given a battery of six experimental tasks, (Wisconsin Card Sorting Test, Spontaneous Alternation, Oddity Problem, Two-Choice Discrimination Learning, Three-Choice Discrimination Learning and Attributes Task) on four separate, equal interval testing occasions over two years. Pre-tests of non-verbal intelligence, verbal comprehension and conceptual tempo were administered, prior to the first testing.

The tasks were selected, following pilot study, to elicit

behavioural evidence of problem-solving strategies, which might be dominant at different ages. Strategy was defined as a reflection of hypothesis forming and testing in a problem for solution.

The results show age-related changes in the use of perseveration and alternation strategies, with indications of more complex strategies available to the 7 year old group. Strategies, once available, were differentially used in tasks within a testing, and appear to be linked to the cognitive demand of a task.

In discussion, it is argued that the results from the use of the longitudinal design support a concept that a further functional system of inhibitory ability is developing from about 4 years of age. Both the hippocampus and frontal lobes appear to be implicated in this system which is seen as the process underlying the development of planning ability and active reduction of error.

It is finally concluded that the emergent system of inhibitory ability is not unitary, but an elaboration of earlier abilities. This is reflected by the changes observed in availability and use by children of strategies for problem-solving. The development of their repertoire thus appears to be by the addition of new strategies, and their elaboration.

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CHAPTER 1

REVIEW OF THE LITERATURE

INTRODUCTION

This Chapter is organised within two major sections. In Section 1, following a definition of terminology, the literature reviewed provides, first, an historical overview of trends in aspects of child development study. Secondly, review is made of studies which have shown age-related changes in children's response tendencies of perseveration and alternation. These are considered to reflect developmental advances in children's abilities to utilise information in problem-solving, and to reduce error. Thirdly, the psychological evidence for age-related development in inhibitory ability is considered. This includes verbal mediation, conceptual tempo, selective attention and some aspects of meta-memory, each of which is argued to indicate the development of planning ability in the active reduction of error. Fourthly, some psychological explanations for the development and nature of inhibition are considered, and in the final part of Section 1, implications for methods of study are reviewed.

Section II considers some aspects of neuro-psychological and other relevant studies of lesion and development of the frontal lobes and hippocampus which have been argued to be implicated in the development of inhibition. These provide correlational evidence that inhibitory changes within the C.N.S. underlie behavioural changes in the use of problem-solving strategies by the age group studied between 3 and 9 years. The difficulties of inferring central processes from behavioural evidence are considered.

I PSYCHOLOGICAL STUDIES OF CHANGES IN CHILDREN'S PROBLEM-SOLVING STRATEGIES

Perseveration and alternation : definitions and historical overview Behavioural Studies

Perseveration is defined as the repetition of a response, and alternation, literally, as the switching from one response to another. Both perseveration and alternation, as behavioural phenomena, have been observed in a wide variety of comparative studies of infra-human species, from guinea pigs, kittens, or rats, through the phylogenetic scale to chimpanzees. Extending from these, comparisons have been made between the behaviour of monkeys, chimpanzees and children. An evolutionary perspective underlay this comparison paralleled by the many experimental studies in the behaviourist tradition of workers such as Watson and Skinner, from which conditions of learning were considered to apply equally to animal and to humans. Humans were seen simply as a more highly evolved, but not qualitatively different species (Kendler 1963). The studies of Harlow and Harlow (1949) illustrate this tradition. Monkeys were found to learn, through trial and error, an oddity problem of 24 trials better than young children, although children with increasing age became more successful in making a reversal.

Another typical study by Schusterman (1963) compared three groups of children (mean ages 3.0 years, N=9; 5.1 years, N=31; 10.8 years, N=34) with chimpanzees aged between 11 and 40 years (N=17) using a two-choice problem consisting of a 50-50 probability series. Pre-training, in which both positions were rewarded, was given to all subjects. Analysis for pre-training data showed that 3 year olds tended to win-stay and 5 year olds to win-shift. 3 year olds were thus perseverating, while 5 year olds alternated. Chimpanzees and 10 year old children did not show either of these response tendencies at a statistically significant level.

In the following trials, each subject received one of four training and experimental conditions:

(a) initial 100% training, consisting of continuous reinforcement at one position to criterion of 15 consecutive errorless trials followed by a long-run 50-50 probability series;

(b) initial 100% training, followed by a short-run 50-50 probability series;

(c) long-run 50-50 probability series made without initial 100% training and;

(d) a short-run series without initial 100% training.

Within the equal probability of occurrence in each condition, a patterning effect was introduced in the sequence of reinforcement, so that the probability for each side was .64 in long-run series, and .39 in short-run. Responses were categorised into preferred and non-preferred positions, and results indicated win-stay, lose-shift strategies for chimpanzees ($p<.02$) and the tendency to win-stay was stronger for those receiving initial training ($p<.05$). 3 year old children also showed stronger tendencies to win-stay than did 5 year olds (long-run $p<.05$, short-run $p<.02$). Similarly, they used a greater lose-shift strategy than 5 year olds under the short-run condition ($p<.05$). Equally, 5 year olds demonstrated a significantly greater lose-shift strategy than did 10 year olds (100% training short-run $p<.05$ and no training short-run $p<.05$).

The overall finding was that three year olds were least sensitive to the task conditions, and that sensitivity increased over age. This is suggestive of a developmental trend towards utilising the cues given in a probability matching task. The alternation tendency noted in 5 year old children, and who appear to favour change for its own sake, is of particular interest. Schusterman (1963) concludes from his study and from his review of the literature similar findings (e.g. Kessen and Kessen 1961) where if two choice task conditions do not demand change, 5 year olds will often impose their own.

Schusterman's (1963) study is however methodologically suspect, as can be shown to be the case in similar studies. 3 year olds were not given the initial training which required 15 errorless trials, and which might have been difficult to achieve at this age. The apparatus, too, for chimpanzees differed from that for children, thus on both counts, direct comparison between chimpanzees and the children is unsound. Nevertheless, the work is reported here for its clear relevance to historical trends in developmental studies.

Further changes in response tendencies

A phenomenon noted throughout the literature (e.g. Manley and Miller 1968; Miller, Dee-Wong, Moffat and Manley 1969; Reiber 1966) that an increase in alternation over age in rewarded and unrewarded conditions, is followed by a decrease, indicating non-linear trends. An inverted U shape describes the typical curve found. The decline in simple alternation and increase in more complex patterns noted for older age groups has been linked with ascent of the phylogenetic scale, and ontogenetic changes. An illustrative example is the work of Gellerman (1931) who extended his work in double alternation using a maze problem in monkeys, raccoons and rats to children and adults. Although an age-related trend in ease of learning the problem was reported, the study was flawed by the attempt to generalise from extremely small numbers in each of the age groups from 3 to 23 years. For example, there was one subject only at each of ages 3, 4 and 23. This descriptive study nevertheless has interest from the recognition noted by Gellerman, that humans cannot be starved or punished as can animals, and that verbal processes become relevant in human developmental studies in choice behaviour. Verbal mediational processes and also changes in response tendencies are reviewed later in this chapter.

Types of studies indicating age-related changes in children's response tendencies

A considerable number of studies have demonstrated age-related changes from perseveration to alternation in children. These can be grouped into those which use reinforcement in

(a) Two choice discrimination learning (e.g. Reiber 1966; Lynn and Compton 1966; de V Peters 1979; Beth Casey 1975; Eimas 1969)

(b) Two choice probability/guessing tasks (Jones and Liverant 1960; Kessen and Kessen 1961; Jones 1970; Derks and Paclisanu 1967; Bogartz 1966; Bogartz and Pedersen 1966)

(c) Spontaneous Alternation (Schusterman 1963; Frith 1970a, 1970b; Douglas 1972, 1975; Manley and Miller 1968; Miller et al 1969)

(d) Three Choice Discrimination Learning (Stevenson and Weir 1963; Weir 1962, 1964, 1967, 1968; 1972; Gruen and Weir, 1964 ; Weir and Gruen 1965; Wittig and Weir 1971; Abe 1975; Odom and Coon 1966)

(e) Discrimination Learning with four or more stimuli (Levine 1966; Phillips and Levine 1975; Gholson, Levine and Phillips 1972; Cantor and Spiker 1978; Scholnick, Osler and Katzenellenbogen 1968; Spiker and Cantor 1979)

Direct comparison between tasks is not possible, even within apparently similar paradigms e.g. two choice discrimination learning. Variations in methodologies, instructions, method of presentation, materials or rewards preclude this, as do other variations in age in months, or social composition of the samples. These aspects are discussed by Goulet and Goodwin (1970) in a most comprehensive review, to be referred to later in this section. However, all the studies cited have demonstrated that the strategy of children below the age of 4 years is likely to be perseveration, and that above 4 years is more likely to be alternation. In the probability/

guessing tasks, analysis of results revealed age-related trends in adapting guesses to the actual probabilities. Jones and Liverant (1960), as a typical example, found that nursery school aged pupils (4-6 years) were more likely than fourth and fifth grade pupils (9-11 years) to use a pure strategy, i.e. choose the maximally reinforced alternative, on both 70-30 and 90-10 series. Reversal behaviour also differed significantly between the age groups, and fourth and fifth grade children made this more quickly than the nursery age group.

However, a point of interest is that data from seven of the 80 subjects across both age groups was not included in analysis because they did not use either strategy. Since raw data was not provided, it is not possible to gauge whether, instead, a simple alternating strategy was used, and which is shown to be dominant from children older than 4 years. Dichotomising data is arguably useful for purposes of analysis, but may lead to a loss of information of psychological if not statistical significance. Nevertheless, Jones and Liverant's work, like that of Kessen and Kessen (1961) adds further support to a concept of age-related development in active error reduction.

The interest in use of approximating strategies was considerable during the 1960s, and was further expressed in studies of three choice discrimination learning.

Principal among these was Weir's (1964) work, in which he carried out a meta-analysis of data gained from previous studies (Gruen and Weir 1964; Stevenson and Weir 1959, 1963). The subjects were 290 children, adolescents and adults, and details of these are given as Table 1.

Table 1
Three Choice Discrimination Learning - Sample size and mean age for each reinforcement condition

x age	N	x age	N
3.6	10	3.6	10
5.5	27	5.5	35
7.0	31	7.3	20
9.2	15	9.1	15
10.8	26	13.3	10
14.8	26	18.0	30
18.0	35		

Total 170 Total 120

The task used a simultaneous procedure, with contingent information feedback and was response defined (Goulet and Goodwin 1970). These characteristics of the task need to be taken into account when search is made for confirming or refuting evidence from the research literature. For each subject one of three knobs was designated correct, but was rewarded only 66% or 33% of the time it was chosen. The results indicated that the number of correct choices made by 3 year olds was equalled only by the college students and that all other age groups made considerably fewer correct choices. A U shaped function was said to describe the data, and to be accounted for by the tendency of the youngest and oldest groups to maximise i.e. choose the only knob which ever gave a payoff. By contrast, the intervening age groups showed a tendency to alternate choices across all three knobs.

Weir suggested that his findings may be accounted for by an age-related increase in ability of children to generate complex hypotheses but that there is mismatch between this and the ability to process information.

He attempted to test this hypothesis in two subsequent experiments (1967, 1968) using the same apparatus and method as previously but with the addition of a memory board to allow children to keep track of previous choices and reward outcomes. Results indicated that 6 year old children's performance was impaired by the use of the memory aid (Weir 1967), but for 9 year olds, an initial finding of benefit on performance was not replicated (1968). The impairment of the younger children's performance prompts the speculation that the memory board acted as a distraction, and points to a fruitful line for research into the relationship between memory and attentional processes.

It is worth noting that a study by Abe (1975), carried out in Japan, used apparatus which differed hardly at all from that used by Weir and his associates. Abe classified his data into types of strategy being used by children aged between 3 and 12 years, and found that the adverse effects of position perseveration on correct responses was most marked in his 3 year old group. For this age group, results did not agree with those of Weir (1964). There was more agreement with Weir's data at the 7 - 9 year old level and a further point of interest was that the older the subject, the later the criterion of ten successive correct responses was reached.

This leads to the possibility that the form of words influenced the performance of the subjects in Abe's study (1975) and that of Weir (1964). Weir's subjects and also those of Abe (1975) were told that if they chose the correct knob a marble would come out. This may have suggested to subjects that if a marble did not come out, they were not correct, and consequently they may have begun to scan across all three knobs. Leading from this may be the formulation of a hypothesis by intervening age group subjects that a patterned response was demanded by the task, and such patterned responses were indeed noted by Weir (1964). If this is so, then the number of correct responses would be correspondingly reduced. This is a possible explanation of results which are inconsistent with those from other studies (e.g. Schusterman 1963; Reiber 1966; Bogartz 1966). Where the demands of a task match the dominant strategy of children, solution is more likely (Goulet and Goodwin 1970), but a crucial point here is whether experimenter and subject 'see' the problem in the same way. Here it is being suggested that, since alternation appears to be the preferred response of Weir's intervening age groups, and that the instructions may have led them to perceive the task as demanding this strategy, the combination may have misled the children to a considerable extent. However, other evidence also from Weir (Gruen and Weir 1964) tends to weaken this hypothesis. Telling some subjects that a marble could not be won each time appeared to have little effect on performance. Weir (1964) noted that subjects appeared not to expect randomness in reinforcement.

The effects of instruction remain unclear, but it may be supposed that the youngest children may be least affected by the form of words, particuarly since the length of the instructions given in the studies reported by Weir (1964) may have exceeded the 3 year olds' information processing capacity. Weir's 3 year old subjects appear to have been highly successful in choosing the correct knob at a mean level of six out of the first ten trials. Their success rate indicates that, either fortuitously, individual subjects chose the correct knob designated correct for them at or near the start of the trials and maintained their choice, or that, unusually for their age group, they were able to utilise error and switch response.

A distinction, too, needs to be made between probabilistic and discrimination learning tasks. Moran and McCullars (1979) draw attention to an important difference between the two types of task i.e. probabilistic learning tasks, where events sum to unity and more than one choice of stimulus may be rewarded, and discrimination learning tasks where there is only one partially reinforced stimulus. They point out that the Weir task is of the latter kind, and, with Goulet and Goodwin (1970), argue that a strategy appropriate for the one may not be adaptive for the other. Much of the research quoted as giving support to other studies has tended to blur the distinction between the two types of task, and Weir's citing of, for example, Jones and Liverant (1960) is no exception. Wohlwill (1973), has also, in an extensive survey of methodologies for the study of behavioural development, suggested that the evidence from the Weir series of studies was inconclusive. However, the focussing of research upon processes in child development was an important outcome of the work developed by Weir (Stevenson and Weir 1959, 1963; Weir 1962, 1964; Gruen and Weir 1964; Weir and Gruen 1965; Weir 1967, 1968) from that begun by Stevenson and Zigler (1958). These studies marked the beginnings of a shift away from a preoccupation with mathematical models, and methodologies drawn from comparative work with infra-human species or human adults, towards research techniques more appropriate for the study of child cognition. One exception to this is the most recent work of Weir (Wittig and Weir 1971; Weir 1972) which explored the contingency or non-contingency of reinforcement on choice of higher probability of two or four alternatives. Although children aged 3.5 and 5.5. years are the subject of these studies (Wittig and

Weir 1971) the literature drawn upon uses largely adult subjects, and the second study is of introductory class psychology students (Weir 1972).

<u>Studies of children's and adults' hypothesis testing behavior</u>
The same blurring of possibilities of qualitative difference in hypothesis formation and testing, i.e. strategy use, between adults and particularly young children, marked the work of Eimas (1969), Gholson, Levine and Phillips (1972), Phillips and Levine (1975), Cantor and Spiker (1978), Spiker and Cantor (1979). Earlier work by Levine (1966) had defined the basic experimental paradigm of the use of a 'blank trial' procedure, with 'introtact probes', questioning procedures. This has been administered to young adults (Levine 1966), adults and children (Eimas 1969; Gholson, Levine and Phillips 1972; Phillips and Levine 1975) and children of kindergarten and 1st grade levels (Cantor and Spiker 1978; Spiker and Cantor 1979). The procedure consisted of a series of reinforced trials, followed by a series without non-reinforcement (blank trials).

The assumptions were that the set of hypotheses held by a subject is finite, that he selects one from the set, and that this acts as a predictor for subsequent trials. If there is no outcome (blank trial), the subject is assumed to continue to hold the previously confirmed hypothesis throughout the blank trials in the belief that he is still correct. These assumptions defined H. theory (Levine 1966) and issues arising from these are discussed in the section on the significance of perseveration in childhood, with reference to Restle's (1962) work on cue learning. The studies cited gave general support to a developmental shift from stereotyped responses of stimulus preference, position perseveration and alternation, towards hypothesis checking, dimension checking and focussing strategies, and therefore to a concept of age-related active error reduction. However, the data gained was not easily interpreted, and in Gholson, Levine and Phillips' study (1972) nearly half of the children's responses were unclassifiable. They considered that further research using less cumbersome methods of analysis was needed. It is possible that one problem in their work arose from a further, though unexplored, underlying assumption of H theory (Levine 1966) that young children's hypothesising abilities stand in continuous relationship to those of older children or adults, and are not qualitatively different. Toppino's (1980) work is of relevance. He reviewed literature which gave support to the general finding that kindergarten children find difficulty in rejecting irrelevant dimensions. This is further considered in relation to studies of developmental changes in selective attention ability, and which may find parallel in Pribram's (1973) conclusions on cognitive deficits in frontal lobe lesion. Pribram's work is reviewed in Section II of this chapter.

Toppino (1980), in three experiments on 96 children ($\bar{x}$ age 68.6 months), found inferential deficits in their solutions to concept-like problems. The problems were similar to those used by Bruner, Goodnow and Austin (1956), Gholson, Levine and Phillips (1972) and Spiker and Cantor (1979). The children performed better in problems where the set of stimulus attributes was a sub-set of the set of possible solutions than those where this was not the case. This was so for both positive instances ($p < .025$) and for negative instances ($p < .001$). Three interpretations of the results of the first experiment were considered. First, that children know the correct rules, but are unable to keep track of successive decisions. Secondly, that children's performance is affected by the nature of their inferential rules which are adequate for positive instances, but not for negative instances. The third interpretation, which was subsequently supported by the second and third experiments, was that children have a more general inferential deficit for utilising uninformative (negative) attributes. This interpretation is consistent with that of Bryant (1982) which is reviewed on page 69. Toppino (1980) considered that his results agreed with those of Inhelder and Piaget (1964) i.e. that young children have difficulty in co-ordinating information and this is further discussed in relation to Piagetian studies. Bryant (1974) has also argued that young children are able to make passive, as distinct from active, inference.

Verbal behaviour in problem solving

The use of verbal guidance and feedback from children indicated discontinuities between expressed understanding of the correct dimension and childrens' ability to respond in accordance with it. This is similar to the findings of Cantor and Spiker (1978). They, in common with Levine (1966), Eimas (1969), Gholson, Levine and Phillips (1972), Phillips and Levine (1975) and Subsequently Spiker and Cantor (1979), used verbal questioning (introtact probes) designed to elicit which hypothesis was being tested. For kindergarten children, 'probes' (questions) given prior to each trial made for inferior performance to that obtained when a single probe was given before the first trial (Cantor and Spiker 1978). Two issues arise from this. First, the repeated giving of probes may have intervened between hypothesis and its subsequent testing, and thus acted as a distractor, since verbal expression of hypothesis was not always reflected in the event. Secondly, verbalisation does not stand in simple relationship to children's choice behaviour. This was demonstrated by Zeiler (1967) who commented on Kuenne's (1946) work on transposition, and suggested that the effect of overt verbalisation in choice behaviour is not always un-ambiguous, especially in younger children. Zeiler (1967) found with 4-5 year old children, that there was no apparent difference between those who verbalised and those who did not. He suggested that verbalisation may be a response produced to verbal stimuli present after the test. This does not necessarily indicate that verbal responses played a part in the discrimination choice behaviour (Zeiler and Gardner 1966). Much variability in the experimental results seemed to be due to factors other than verbal stimuli. This was found across all subjects, and so was unlikely to be due to individual differences. Although Zeiler's conclusions concerned verbal responses made after, rather than before the event, as with e.g. Cantor and Spiker (1978), the point is nevertheless made that, at younger ages, children's verbalisation and actions may not match. It is precisely this which has led to some methodological discussions of Piaget's work (Bryant 1982). Verbalisation of a concept appears to confirm its presence, but inadequate verbalisation does not necessarily indicate absence of that concept. This point is relevant to the oddity problem, which was first described by Harlow (1949), and used by Piaget (Inhelder and Piaget 1964).

Piaget thought of the oddity problem as an instance of a singular class which was considered to be a difficult concept for children up to about 8 or 9 years. Three stages were identified, and in stages I and II, before approximately 7 years, a 50% chance of success only was shown, corresponding, according to Piaget, to solution by sensori-motor learning. From 7-9 years, the proportion of successes was 76%, but children from 10-12 years showed only a 33% success rate which, Piaget suggested, was due to the introduction by the children of imaginary complications.

In unpublished research reported by Lunzer (1968) who criticised Inhelder and Piaget's methodology and reporting, he and Astin tested 6 children at all ages between 4 and 10 years on a version of the oddity problem. 120 trials were given, consisting of 6 trials of each of 20 problems, followed by a further 5 problems of one trial each. At a third stage, the child was asked to give the rule and to pose a further 5 problems for the experimenter to solve. Only one four year old failed to learn at the first stage, but not until the age 8 could children give a satisfactory explanation or pose similar problems. Lunzer (1968) considered this difference to indicate qualitative differences in the learning by older, as distinct from younger children, and to give general support to Inhelder and Piaget's findings, although without the decline in performance by the oldest group. The qualitative difference is thought to be in representational ability used to guide behaviour, which younger children may lack.

This point is relevant to the continuing debate on the relationship between language and cognition (e.g. Harris 1982) and to differences between Piaget's (1959) early position and that of Luria (1961 or Vygotsky (1962). It is further considered with reference to the Kendlers' work (1963, 1967) on mediational processes (page 40)

Luria (1961) considered that response inhibition is poor in young children. In several experiments Luria (1961) showed that younger children are initially able to follow commands calling for action, but are not able to restrain ongoing action. Before 4-5 years, the child is able to respond to the command 'press', but not able to restrain pressing for the command 'don't press'. At this point, language is functioning as a first signalling system and not by its semantic content as a second signalling system. In another experiment, when language was used to change the relative strength of a stimulus, Luria (1961) noted that 4-5 years appears to be an intermediate stage between non-adaptation and more stable adaptation to verbal stimuli. He suggested that 4-5 years is crucial in the use of internalised speech, and that this must be closely related to maturation, in that some internal system of feedback has been developed. This he linked to development of frontal lobe systems, and which is discussed on page 93 Such an internal system may be the means by which as Vygotsky (1962) suggests, speech becomes an instrument for planning and representation. The development of planning abilities is considered on page 59.

Whether verbalisation is cause or correlate of behavioural transition is an unresolved issue (White 1965), but its importance was emphasised by the Russian psychologist, Leontiev (1932), who wrote that during the school years, children became less reliant on external means of organising behaviour and that behaviour becomes internally mediated. This comment is consistent with Luria's position on the role of frontal lobe maturation in childhood, and which is discussed in section II of this chapter.

Experiments to test Luria's hypothesis on the development of verbal self regulation have been carried out by Miller, Shelton and Flavell (1970), using a button pressing test with four groups of children aged between 3 and 5 years, and by Strommen (1973), who tested pre-school, kindergarten, 1st and 3rd grade children on a version of 'Simon Says'. Both sets of experiments supported a view of age-related development in the ability to inhibit responses. In Miller, Shelton and Flavell's work (1970), the enforced use of verbalisation in three of the four conditions appeared to be an additional task for the children at each of the age groups. The fourth condition required only a motor and therefore silent response. To that extent, their results did not support Luria's position that verbal self-instruction interacts with age. It should, however, be pointed out that enforced verbalisation is not to be equated with spontaneous verbal regulation of behaviour, and it is this second aspect which formed the substance of Luria's argument.

Work by Flavell, Beach and Chinsky (1966) considered that a production deficit could account for children's failure to verbalise in a memorising task, although the competence to do so was available. This is relevant to Strommen's (1973) work, and to subsequent study by the writer (1976).

Strommen, using a Simon Says task, had originally considered the task analogous to the classic Luria (1961) bulb-pressing task. However, the performance of the children led her to the conclusion that the ability to inhibit impulse was dependent on task and situation.

Although errors decreased with grade and therefore age of the children, Strommen stated that there were still 'many errors' at mean age 7 years. Some sex differences, too, were shown, and girls of all ages tested, improved over the two 10 trial blocks, but younger boys (pre-school, mediam age 4.9 years, and kindergarten, median age 5.10 years) did not. The combination of making the statement 'Simon Says, do this' together with the execution of the action, apparently served to disinhibit the child's action. This will be discussed further, when reviewing White's (1965) review of developmental changes between 5 and 7 years.

Further evidence that age-related changes occur in children's ability to inhibit response by means of another's verbal direction was provided by an experiment carried out by the writer (1976). 96 children who were subjects of the experiment in spontaneous alternation to be described on page 74 were given a Simon Says task. After practice in touching or not touching appropriate parts of the body (e.g. Simon Says Touch ear/Touch eye) the experiment consisted of 20 successive discriminations. Results from two way ANOVA gave significant main effects for age ($p< .001$). A Tukey A test was also computed, and the range statistic of 2.33 was used for pairwise comparison of means for the six age groups. Means for the younger groups of children (3.0-3.11 years, 4.0-4.11 years) were significantly different from all the age groups, and, separately, that means from 8.0-8.11 age group were significantly different to all others. There was also a highly significantly linear trend ($p < .001$), and that 62% of variance in response inhibition was accounted for by age. It is noted that the children in this study were not asked to verbalise, and that this difference in procedure from that of Strommen, may have contributed to their success in inhibiting response.

These results provided supporting evidence that external verbalisation increasingly guided children's ability to inhibit response, but it cannot necessarily be assumed from this that there was internally directed verbal mediation between stimulus and response. Before discussing experiments designed to test the hypothesis that verbal mediational processes facilitate a transition in ease of making reversal shifts (Kendler 1963), it is noteworthy arising from Strommen (1973) conclusions, that work carried out in Luria's laboratory by his collaborators (Luria 1961), showed that instructions that facilitated imaging, increased inhibition of response. It seems possible, too, that temperamental factors may influence the degree of inhibitory self control (Reed, Pien and Rothbart 1984). This is considered on page 57.

Mediational processes

Much of the earlier research has suggested a mediating process, an hypothesised internal event, interposed between stimulus and response, to account for the changes occurring in children's problem-solving from around 4 years of age.

Since differences between animal and human behaviour are most clearly seen in the language abilities of humans, much of the research of the 1950s and 1960s centered around the hypothesis that language provides the mediational link between stimulus and response, and replaces a single-unit mode of responding. Noteworthy in this field have been the Kendlers (1963, 1967, 1970), who have carried out considerable empirical work into the development of inferential behaviour in children and adults. Several of their experiments have been concerned with discrimination learning of reversal and non-reversal shift tasks, and these suggest that non-reversal shift tasks are more readily learned by rats and young children, whereas older children and college students are more able to learn a reversal shift. T S Kendler (1963) used two pairs of stimulus cards, large black, and small white, large white, and small black, to test the hypothesis that the use of verbal labels facilitated the learning of reversal shift tasks, and that depending on which criterion, size or colour, the child responded to, he was categorised as a mediator or non-mediator. However, the premises on which such a categorisation rests are not strong, and it was suggested by Kendler (1963) that the child may respond to both e.g. smallness and whiteness. Nevertheless, Kendler's main findings were that there is a sharp increase in the ability to learn both reversal and non-reversal shift tasks between 43 and 54 months. That some mediational process is at work seems likely from this work, but it is not clear that use of language is a wholly adequate explanation (White 1965).

Kendler and Kendler (1967) were puzzled by the number of children who made initial correct choices, and then failed to act on them to obtain the goal, and so speculated on whether this was a failure to attend to relevant sub-goals. They also considered level of intellectual functions as being relevant to that of task complexity. Their subsequent experiments took intelligence into account, as well as age, through the use of the Peabody Picture Vocabulary Test, but it is dubious whether a vocabulary test is an adequate test of intelligence. A number of younger children in kindergarten never solved the problem, in spite of pressing the button that made the relevant subgoal available, and there were a number who either pressed the same button repeatedly, or alternated between pressing one button and then the other. Their assumption had been that when there are few alternatives, the correct one will be found and acted upon. Motivational factors did not appear to provide an explanation, and they concluded that maturation increases the ability to solve problems or attain a goal by spontaneously organising a set of behaviour segments into a novel arrangement, as is the prediction under a Hullian paradigm. However, maturation is a somewhat global term, and the functions ascribed to the frontal lobe systems is suggested as a more specific use of the term (Section II).

Kendler and Kendler (1967) commenting on their own earlier work in reversal and non-reversal shift in discrimination learning, suggest salient phylogenetic and ontogenetic developmental differences in the availability of relevant mediating response mechanisms, and that these appear to be in part age and species related. In Hullian theory, this might be the availability of anticipatory representational responses in inferential tasks, and Kendler and Kendler (1967) suggested that these may be alternatively idiosyncratic or universal, linguistic or not, central or peripheral. Their inclusive suggestions followed on their findings, which were not unequivocal, of the variable effects of providing verbal labels, and the source of variation produced by children's alternating responses, and of the interaction of age with verbal label. Linguistic labels may be used by older children because they are often readily available, but their use is not synonymous with representational responses,(Flavell, Beach and Chinsky 1966).

A commonsense statement is, that as symbolic representations in linguistic terms develop, there will be an increased likelihood of their use, and thus for verbal mediational processes to intervene between stimulus and response. In a study designed to elicit a relationship between postulated mediationally induced reversal shifts and other tasks of transposition, category clustering, and paired associates, Ash (1975) concluded that results of these tasks with third grade children (age range 101-125 months) supported an age-related trend in ease of making an optional reversal shift. More importantly, his findings suggested, consistent with Kendler and Hynds (1974, that mediational processes do not develop in an abrupt and saltatory manner, but the likelihood of their being used increases in strength. From this, it is suggested that if mediational processes can be considered to reflect developing inhibitory functions, they too, cannot be an all or nothing activity. It could be argued, in line with White's (1965) statement supported by Denney (1972, 1973) and Egelund (1974) that task specificity and situational factors are influential in whether a response is inhibited. Perhaps even more speculative would be the possibility of level of CNS organisation and inhibitory ability, and which is fully reviewed in Section II. Illustrative of such a possibility would be Schaffer's (1974) argument on cognitive components of response by infants to strangeness. He used Luria's definition of inhibition, to consider two events simultaneously e.g. two simultaneous excitations which give rise to inhibition, and applied these to infants' perception of strangeness. He suggested that inhibitory capacities became available at different times, phylogenetically older or lower level brain systems before newer and higher systems. In support, Schaffer cited Luria's work in verbal regulation of behaviour as of a higher order than motor behaviour.

Levels of organisation in problem-solving abilities

This interpretation has construct validity in the light of evidence concerning memory and search behaviour in infants, some of which is considered in the discussion of a pilot study carried out for this research in 1979 as a preliminary to the main study (Appendix 1 . In particular, it is noted from Butterworth and Jarrett's (1982) study of a Stage IV, object permanence task, that even young infants do not necessarily perseverate, but switch search behaviour for the hidden object. Perseveration would be predicted if no inhibitory ability was available. Sophian and Wellman (1983) compared search behaviour on a Stage IV task with 9 month old, 16 month old, 2 years, 2½ years and 4 year old children. 16 month old children were less likely to perseverate than 9 month old, and more readily corrected errors. In their second experiment with 9 and 16 month old infants, and with 2, 2½ and 4 year old children, Sophian and Wellman showed age-related improvement in children's ability to select between competing sources of information. 16 month old infants, too, had some ability to be selective.

Nevertheless, although they argued that perseveration is not the inevitable strategy used by infants and young children, the inference from these, and similar studies, is that error reduction takes place at a lower level of cognitive organisation. However, it is not clear whether this is the form which is said to define internal inhibition, to be discussed on page 97. Using a very different methodology and terminology, which presents difficulties of mapping between theories of development, Piaget used the term vertical decalage to account for the progressive restructuring of levels of function. This contrasts with his concept of horizontal decalage in which logical problem-solving abilities at a given level of intellectual organisation are task-dependent. (The Piagetian position is further considered on page 63) This concept is consistent with the position of Donaldson (1978) who argued from her experiments that more advanced strategies are used by children in situations which make 'human sense' i.e. those that stem from a familiar context. It is also consistent with the literature suggesting a temporal stacking of behaviours (White 1965) conceptual tempo (Denney 1972, 1973; Egelund 1974) and the construct of disinhibition (Douglas 1972, 1975; Gray 1975). Each of these is more fully discussed later in the chapter.

Donaldson's (1978) work is part of a growing body of literature which suggests that the pre-school age child has considerable competence in de-centering behaviour.

Schatz and Gelman (1973), in three studies of 4 year old children's communicative abilities, showed 4 year olds adapted their speech to the age of the listener. Speech to 2 year olds used shorter, simpler sentences, than to their peers and to adults. Gelman and Gallistel (1983) have shown that 2, 3 and 4 year old children have more knowledge of number and invariance than has been supposed from Piaget's results (1941). Although these studies illustrate areas of competence in pre-school aged children, there are, equally, many which suggest that major developmental advances are made from the fifth year. Those relating to response tendencies have already been reviewed, and the contribution of White (1965) is now considered.

S H White's model of cognitive change as hierarchical

White considered that there was evidence for an hierarchical arrangement of learning processes, and began with considering the, then current, interpretation of the transition from learning behaviour akin to that of animals to a 'human-like' mode of learning as essentially a new mediational view of language. He additionally considered the possibility of an inhibitory mechanism as underlying the temporal stacking and availability of responses. Within the text, White (1965) reviewed and presented, as a summarised table, the literature on behavioural change occurring between 5 and 7 years. This is reproduced as Table 2.

Table 2 Summary of Behaviour Changes for Age 5 to Age 7

TABLE III (extracted from page 209)
SUMMARY OF BEHAVIOR CHANGES FROM AGE 5 TO AGE 7

Younger pattern	Older pattern	Source
(1) Near but not far transposition	Near and far transposition	Kuenne (1946)
(2) Nonreversal shift easier	Reversal shift easier	Kendler & Kendler (1962a)
(3) Classical conditioning increasing	Classical conditioning decreasing	Razran (1933)
(4) Varying position hinders discrimination	Varying position helps discrimination	White (1965b)
(5) Varying positive cue hinders discrimination	Varying positive cue neutral	White (1965b)
(6) Little direct inference	Frequent direct inference	Kendler & Kendler (1962b)
(7) Simple discrimination improves	Simple discrimination declines	Weir & Stevenson (1962)
(8) Prefer tactual exploring	Prefer visual exploring	Schopler (1964)
(9) Color or mixed dominance	Form dominance	Brian & Goodenough (1929)
(10) No left-right sense	Personal left-right	Piaget (1959)
(11) Form, word, and letter reversals	Decline in reversals	Davidson (1934, 1935)
(12) Easily disoriented	Resists disorienting	Emerson (1931)
(13) Fails face-hand test	Passes face-hand test	Fink & Bender (1953)
(14) Increasing prediction of adult IQ	Maximal prediction of adult IQ	Bayley (1949)
(15) Factors I and II account for IQ	Factor III principal factor	Hofstaetter (1954)
(16) Speech expressive and instrumental	Speech internalized	Vygotsky (1962)
(17) Word associations syntagmatic	Word associations paradigmatic	Ervin (1961)
(18) Lesser effect of DAF	Greater effect of DAF	Chase *et al.* (1961)
(19) Little planning before drawing	Planning before drawing	Hetzer (1926)
(20) Difficulty drawing "largest" and "smallest" squares	Can perform task	Piaget (1960c)
(21) Reinforced by praise	Reinforced by correctness	Zigler & Kanzer (1962)

from S H White Evidence for a Hierarchical Arrangement of Learning Processes (1965)

In general, White (1965) sums up the changes as reflecting an hierarchical development from a predominantly associative mode of learning to a predominantly cognitive mode. In such a model, the associative mode is not lost, but is inhibited by the cognitive function. In a stressful situation, a first available associative response may be disinhibited. It is of interest here that theta waves which normally decline by age 6, may be re-evoked in anger or frustration in both children and adults (Marshall 1968). However, the re-evoking of theta in adults due to stress, is a suggestion coming from only one study, and there is other evidence which has another direction, e.g. Douglas (1972, 1975), who has interpreted theta activity as demonstrating hippocampal function, and the onset of internal inhibition.

Support for White's (1965) suggestions comes also from the work of Denney et al (1972, 1973) on conceptual tempo, and their evidence of developmental change between 5 and 7 years from an impulsive to a more reflective tempo. Attempts by Egelund (1974) to train children in a more reflective mode of behaviour met with only limited success, and under stress, children appear to revert to an impulsive mode, again suggesting a disinhibition of behaviour. Implications of this are discussed with reference to the impulsive - reflective dimension on page 69 This links with the discussion on page 70 on development of internal inhibition, which, in Pavlovian theory, is seen as an actively generated brain process based primarily on non-reinforcement (Douglas 1972). The inhibition is of an opposed excitation process, and the two mutually antagonise and induce each other. Douglas (1972) suggested that internal inhibition is more labile than excitation and is checked by disinhibition, which is an 'inhibition of internal inhibition' (Gray 1975). Whether the terms 'inhibition' or 'disinhibition' are more safely used in an operational sense, or directly linked to CNS maturation, is a matter of debate through continuing research.

Inhibition and the impulsive-reflective dimension

A recent study (Reed, Pien and Rothbart 1984) found evidence to support inhibitory abilities in children aged 40-49 months. They used four tasks, Spontaneous Alternation (after Douglas 1975), Simon Says (using body parts, and similar to the task constructed by Clayfield 1976), Pinball game and Drawing Task, within a conceptual framework defined by the work of Pavlov discussed and extended by Douglas (1972, 1975) on the development of internal inhibition. Reed, Pien and Rothbart (1984) suggest, from their findings that inhibition across tasks was significantly correlated with age, that the transition from perseveration to alternation in the Spontaneous Alternation task in the 4th year was evidence for internal inhibition ability. They linked this to both development of the hippocampus and to stable individual differences in inhibitory ability. However, since this work was cross-sectional, the individual differences reflected in performance may be related to situational variability within the single test occasion, rather than stable behavioural tendencies.

There does appear to be evidence that cognitive style, which includes conceptual tempo, reflect individual differences, other than those which are age-related.

Kagan (1964,1965a) identified an impulsive-reflective dimension of cognitive style, which is classically tested by the Matching Familiar Figures Test. He suggested that there is a tendency for children to become more reflective with age, but that personality variables may influence responses later in time, on error behaviour. More reflective children tend, in general, to make fewer errors, and there does seem to be a relationship between reading ability and conceptual tempo (Kagan 1965b, Roberts 1979). Stein and Prindaville (1976) found evidence from a successive discrimination task,that inhibitory ability was higher in reflective than impulsive children. This was also the finding of Stein and Landis (1975) using a task with differential reinforcements of low rate performance, although the significance level accepted was not orthodox ($p < .08$). It is, of course, possible that a typographical error in stating significance level, had remained undetected before publication.

Social experience variables have been argued to influence the impulsive-reflective dimension (Kagan and Kogan 1970), and that low socio-economic status children make more impulsive errors of perseveration than upper socio-economic group children (Scholnick, Osler, Katzenellenbogen 1968). Impulsivity is also one of the descriptive terms applied to hyperkinetic children, and in a comprehensive review and analysis of the confused area of hyperkinesis, Rosenthal and Allen (1978) suggested that this was due to defective inhibitory processes in the brain. Low levels of serotonin have been reported in the blood of hyperkinetic children, and if these levels genuinely reflect release of mono-amine neuro-transmitters in the brain, then this finding would link with the evidence to be presented in Section II that the hippocampus is served by serotonin pathways. Rosenthal and Allen conclude from a review of neuro-physiological and chemical studies that cortical immaturity underlies hyperkinesis, and cite as further evidence that hyperkinetic childrens' performance is similar to animals with hippocampal and orbito-frontal lesions. (Deficits arising from such lesions are reviewed in Section II of this chapter.) The paradoxical findings that amphetamine acts to reduce hyperkinesis, is argued to support the concept that deficient forebrain inhibition is responsible for the condition, since amphetamines apppear to excite cholinergic neurons, and thus exert inhibitory control.

The development of planning abilities

Zelnicker et al (1977a) found that reflective children asked more 'constraint seeking' questions, and were more efficient problem solvers than impulsive children. It is suggested from this, that reflective children were able to use planning abilities which were conducive to error reduction. There were, however, task-related variations in accuracy (1977b).

A planning factor, as one of three factors, was identified by Hofstaetter (1954) in his factor analysis of longitudinally gained data from California Growth Study reported by Bayley (1949). Hofstaetter's analysis is referred to on page 94 in the context of its apparent similarity to Luria's graphs illustrating maturation and growth of the frontal lobes. He interpreted his results to suggest that a sensori-motor factor (1) accounts for most of the variance between 1-20 months, a persistence factor (2) which reached its maximum between 20-48 months, followed by a planning factor (3) which increased its share of variance from 48 months. He saw the decline in persistence factor (2) as implying a decrease in rigidity and tendency to act in accordance with an established set, and that the emergence of factor (3) (or 'g' factor) to mean the development of provisional action, manipulation of symbols, and the ability to antipate future actions in the present.

Fig. I Factor Analysis of Californian Growth Study Data

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From P Hofstaetter The Changing Composition of Intelligence: A Study in T Technique J Genetic Psychol. 1954, 85 pp 159-164

The development of provisional planning of action is analogous to Inhelder and Piaget's (1964) description of anticipatory schemata, and which is discussed in the next sub-section.

The development of provisional action, or anticipatory schemata, is suggested to be embedded in age-related developments in selective attention. A substantial number of studies (e.g. Pick, Christy and Frankel 1972; Pick and Frankel 1974; Vurpillot 1968; Vurpillot and Ball 1979) have demonstrated age-related development in systematic visual scanning, before judging pairs of stimuli to be the same or different. In each of these studies, older children appeared more able than younger to ignore irrelevant dimensions, and adapted their strategies more readily to the demands of a task. Vurpillot used photographs to record the number and direction of eye movement in 78 children aged 3 and 9.6 years in comparing windows in houses. From around 6 years, children made more fixations before making their judgments, and from this age, errors declined. On page 85, it is noted that Pribram (1971) had suggested use of eye photography to explore the complex issue of attention, although the comment from Neisser and Beckler (1975 is relevant, that eye movements are not the principal 'mechanism' of selective attention but are consequential to it. Gibson and Rader 1979) have argued that attention is a question of knowing what to look for (' the perceiver as performer') and this is similar to the view of Neisser (1976). Nevertheless, it is tempting to speculate that developments in selective attention which imply planning ability are accompaniments of increasing inhibitory abilities.

Some aspects of Piaget's work

The development of selective attention with its concomitants of ability to disregard irrelevant variables may be argued to underlie the progressive emergence of logical thinking abilities. These are epitomised by Piaget's study of classification abilities (1964). Two aspects, the development of additive classification and multiplicative classification are considered of particular relevance to this review. (See Inhelder & Piaget 1964).

In additive classification, one element is selected for sorting from several simultaneously. Between approximate ages 2½ to 5 years, the child, in effect, strays off the point, and from sorting e.g. triangles of various colours from squares, is likely to be distracted by colour and consequently sort on that basis. Later, he may sort to a further irrelevant variable. The connection is through successive perceptual similarities, and thus 'graphic collections' are made from this early centration on one variable ignoring the other, and its converse.

At a later stage, the child is said to oscillate between variables and is beginning to use retro-active schemata (hindsight) and anticipatory schemata (foresight) but there is a disconnection between their use,and he makes a non-graphic collection. Subsequently, the child combines both schemata in an infra-logical grouping, an achievement of concrete operational thinking. Until this point, one source of difficulty for the child appears to be the co-ordination of both spatial and temporal features of a task (Piaget 1964); this has possible links with Pribram's comments on deficits in spatial and temporal organisation in frontal lobe lesion, reviewed in Section II. These have been argued here to be inseparable.

This description of sequence in logical thinking ability bears a striking resemblance to perseveration, followed by alternation (oscillation) strategies, and ultimately active error reduction through use of planning abilities. In the writer's study (1976) the resemblance of Piagetian terminology to describe intellectual processes to that of the internal inhibition concept was explored, and some support found to suggest that development of classification abilities reflected maturation of inhibitory ability. The task used to test this hypothesis was multiplicative classification or Matrices, using the material and methodology of Versey (1974). It was administered to 96 children who were also given a Spontaneous Alternation task, Passive Avoidance task and Simon Says. The results are given on page 74 (Spontaneous Alternation), page 75 (Passive Avoidance) and page 46 (Simon Says). Analysis indicated age-related developments in verbal responses from those representing graphic-collections, through non-graphic to those demonstrating logical inference. A point of relevance here, and to the review on page 41, was that the level of verbal responses did not necessarily reflect that of actual sorting behaviour, but the overall conclusions were that parallels could be drawn between concept development in Piagetian terms, and development of internal inhibition.

Over a long period, Piaget has considered the necessity to postulate neural maturation as the genetic basis for intellectual development, as is shown by his questions to Grey Walter in Tanner and Inhelder (1956) and in Biology and Knowledge (1971). Piaget's terminology has been 'equilibration', or maturational force, which acts to restructure experience. From this the groupings and conservations of the concrete operational stage develop betwen 7-11 years. His argument has been that there may be delayed maturation of a brain structure which, when it becomes functional, accounts for the partial equilibrium at the close of the 'intuitive' substage of pre-operations at 6-7 years.

In terms of the present study, it is argued that anticipatory schemata may be equated with rudimentary planning ability, and that the co-ordination of retro-active and anticipatory schemata are necessary to active error reduction. There would appear to be analogies between Piagetian work and the use of reinforcement and non-reinforcement, as a means of taking account of the past to plan further action. These are hypotheses testing abilities which appear to be emerging from 1st grade level, in the sense used e.g. by Levine (1966), Gholson, Levine and Phillips (1972, Cantor and Spiker (1978) and Spiker and Cantor (1979). The evidence for this was reviewed earlier in this chapter, and added to that which suggests that major developmental cognitive advances are occurring between 5 and 7 years, and which become further elaborated.

One example of further development which may be linked to increasing inhibitory abilities, is children's organisation of remembering (e.g. Flavell 1977). This is not to be narrowly equated with memory capacity, but as is pointed out by Kagan and Kogan (1970), any apparent deficit is in effective deployment of information processing capacity. They suggested that unwanted material exerted an effect on the perception of wanted material. This seems to be a position that might be shared by Gibson and Rader (1979). The need to differentiate memory ability from knowledge about memory has also been discussed by Cavanagh and Perlmutter (1982). Nevertheless in terms of planning abilities, it can be argued that the elaboration of memory abilities shown from around 4 years, when children begin to organise material for recall into conceptual categories (Rossi and Wittrock 1975), reflects the ability to differentiate between relevant and irrelevant aspects. It is suggested that this parallels the advances in visual scanning abilities already reviewed (e.g. Pick and Frankel 1974; Pick, Frankel and Christie 1972; Vurpillot 1968). Similarly, children show age-related advance in understanding attention (Miller and Bigi 1979) and of optimal working conditions of time available, noise or quiet (Yussen and Bird 1979). In this context, it is suggested that if, as suggested, the development of meta-cognitive function is related to the ability to sift relevant from irrelevant information, then this is conceptually active error-reduction and which has been argued throughout the review to be an inhibitory function.

The literature on meta-cognitive abilities, which suggests that these can be detected as beginning from around 4 years, and further elaborated in the primary school years, is of particular interest, since, it appears to be in direct contradiction to the 'zero memory' hypothesis of Restle (1962), on the significance of perseveration.

The significance of perseveration and alternation

Restle (1962) used the term strategy in place of habit or hypothesis in a mathematical formulation of how these are selected and used in a problem. He considered that there were three p ssibilities. The first was that the subject selects a strategy from a finite set to test for solution. If correct, the strategy use is repeated, but if not, it is returned to the set and further sampling from the set takes place, and where, due to its replacement, the incorrect strategy may again be selected. A second possibility that all strategies may be considered at once, and subsequently strategies narrowed down, and thirdly, that a random sample of all strategies may be drawn after error.

The re-use of an erroneous strategy manifested as perseveration or alternation was considered to indicate 'zero memory', a position which stretches credibility given that the literature demonstrates even young babies' memory for a hidden object, and more elaborate memory advances from 4 years. Nevertheless, as the studies reviewed in this chapter have shown, children under about 4 years tend to perseverate, and that at about 4 years, the dominant tendency becomes alternation. On the surface, this presents as 'zero memory', but there is a conceptual problem of assuming that, even if it be the case that each person possesses a finite set of strategies; these can be fully known to another person. Toppino's work (1980), referred to on page 40 , would provide counter-evidence to this proposition, as clearly would the work of Piaget (1964). Instead, the possibility exists that perseveration and alternation reflect the child's inability to differentiate between relevant and irrelevant variables in a problem which is not of that child's setting, and where the significance of the cues available are not understood. This is likely to be most pronounced where non-reinforcement is intended by another to act as a cue, and which might explain the greater likelihood of, for instance, discrimination learning through reinforcement. This would then be consistent with the findings from lesion studies reviewed in Section II, and which relate inability to use cues from error to the absence of internal inhibitory function. The greater likelihood of success from feedback of what is correct was highlighted by Bryant (1982) in a study of conflict and agreement between strategies in childrens' ideas about measurement. Bryant pointed out that information that a strategy is wrong may lead to conflict, but not to solution as Piaget has suggested (1977). Rather, when strategies agreed, the child was led forward. Confirmation, rather than refutation, increased the likelihood of solution.

The same inability to differentiate between relevance and irrelevance in a problem, and therefore to a persistence with an incorrect solution, may be argued to underlie some difficulties of children in the school situation. Bennett, Desforges, Cockburn and Wilkinson (1984) illustrated this point, indirectly, in their study of the problem of the match between task given and child's preparedness to deal with it. A tape-transcript of an interview between Helen aged 6 and a fieldworker showed that Helen's understanding of what a new mathematical task required, rested on her previous understanding that her teacher expected her to use halfpence. In effect, she perseverated inappropriately from her previous classroom experience.

Bennett et al's (1984) study is in the current tradition of naturalistic observations, with interpretation of their significance by the researcher, whereas most of the evidence on inhibitory development has been from laboratory-type experiments. The studies of perseveration and spontaneous alternation next reviewed exemplify this distinction.

Spontaneous alternation as an index of inhibition

Perseveration has been argued by Douglas (1972, 1975, 1976) to be the dominant response tendency in immature rats, guinea pigs and children, and to be due to an absence of internal inhibitory ability. This is defined as the active suppression of response following non-reinforcement, and was a concept developed from the work of Pavlov. With his wife, Douglas tested the theory that this ability develops abruptly at around 4 years of age in children. The test used was a Spontaneous Alternation task, in which children could activate a slide projector to display one of two pictures during 26 trials. Repeated pressing of a button caused the same picture to be shown, whereas alternation of the buttons changed the picture shown. Twenty three children aged between 1.5 years to 6 years were tested, and results showed that only one child below the age of

49 months alternated, although 11 were close to a chance level. The four youngest children were well below a 50% rate of alternation. However, D Douglas (Personal Communication 1976) considered that a difficulty occurs in constructing not only 'a pure test of hippocampal function, but also of keeping their interest'. Some children in her pilot study apparently made complex responses which she interpreted as 'having the intention to trick her, or else to relieve boredom'. The report by R Douglas (1975) showed from these results a drop from near 90% rate of alternation to between 70 and 80% from 5 years as the child developed double and triple alternations; a tendency for this to occur in infra-human species and humans was noted when reviewing Gellerman's (1931) work. It has been hypothesised from lesion and developmental studies of animals, that alternation of choice was behavioural evidence of functional maturation of the hippocampus. These are reviewed in Section II. In relation to children's development, Douglas further hypothesised that internal inhibition was a necessary pre-condition for the conservations described by Piaget. Accordingly, she attempted to test for conservation of volume, but only one child succeeded in conserving. The failure to link conservation to hypothesised development of internal inhibition was not surprising, since conservation of volume is normally associated with development in the concrete to formal operational transition period (Piaget 1974 .

On the basis of a very small sample of children, a sudden rise in alternations did tentatively bear out Douglas' (1972, 1975) hypothesis that, if spontaneous alternation does reflect the onset of adult type hippocampal function in the rat, then, equally, it may do so in the human. The data suggested that this may be at around four years of age. Further studies of spontaneous alternation relevant to strategy use in children are now considered.

Frith (1970a) in two studies of normal children and those diagnosed as autistic studied pattern detection in colour sequences. She found a predominantly perseverative tendency in the 10 autistic children, whose average age was 10.2 years, and predominant alternation in the normal control group of 10 children whose average age was 5.6 years. Errors by normal children were in keeping with the dominant feature of the patterns, whereas the autistic group were insensitive to differences in the structures present, and tended to impose their own stereotyped patterns. She suggested that this is in keeping with Hermelin and O'Connors' (1970) hypothesis that autistic children have a deficit in the central processing of input.

This was further tested in a second experiment (Frith 1970b) by a task involving guessing the colours, red and black, in a randomly shuffled pack of playing cards, and for younger children, in a pack of white cards with either a red square or a black square stuck on. This task was thought to induce the spontaneous production of binary sequences, and reflected the thinking that, children impose their own structure on input which is relatively unstructured. Four groups of children were used, normal nursery school children N=10, average age 3.6 years), normal infant school children (N=10, average age 5.8 years), autistic children attending special school but living at home (N=19, average age 11.7 years) educationally subnormal children (N=20, average age 14.7 years). Of this last group, 8 came from a training school and lived at home, while 12 lived in a residential institution. The mental age of both the autistic and subnormal groups was assumed to be 3-4 years, though the subnormal group from the institution had a slightly lower Peabody Picture Vocabulary Test score. This test has already been suggested to be a poor test of intelligence. The results showed that the normal children under 4 years, the autistic group and those from the institution predominantly perseverated, whereas those from the training school and older normal groups alternated. Of significance here may be the differential experience of the sub-normal group living at home from those in an institution, but as Frith (1970) suggested, these may be a selected group. If Douglas' (1972, 1975) hypothesis that spontaneous alternation reveals active hippocampal function has substance, then the question is raised afresh of the possible effects of environment on development of brain structures and maturation of function. In Section I pp 58,59 , some links between socialisation and the development of inhibitory neuro-transmitters were considered, as well as evidence that disadvantaged children's perseveration behaviour is greater than more advantaged. However, the probably multivariate nature of interaction between maturation of structures, and experience imply daunting methodological problems for design and interpretation.

Further psychological tests of Douglas' theory of internal inhibition

In the writer's previous work (1976) 96 children in six equal age groups between 3-9 years were each given a test of spontaneous alternation, passive avoidance, successive discrimination ('Simon Says') and Multiplicative Classification (Inhelder and Piaget 1964) but using the procedures described by Versey (1974). For spontaneous alternation, results from a 2 way ANOVA indicated a significant main effect for age. Results from Tukey A Test showed that means of all age groups differed significantly from the means of 3-3.11 age group. Both linear and non-linear trends were found. From this, it did appear that major changes from perseveration to alternation take place around 4 years of age, but the significant non-linear trends suggest, too, that simple alternation strategies are replaced by other patterns of choice. In this, the data was in agreement with that of Douglas (1975, 1976). Unexpectedly at the time, the results of passive avoidance showed both perseverative and alternation strategies in the first stage of the tasks, to the extent that children could only be categorised according to whether this stage was learned or not. Few children at 3 or 4 years, learned the tasks compared with older age groups. The task was methodologically flawed on a number of counts, including that of assuming that removal of previously gained rewards in the second stage could be considered to be the equivalent of electric shocks in a shuttle box. It was, however, of considerable interest, in the evidence obtained, of the ubiquity of age-related tendencies to perseverate or alternate, and that for younger children, this transcended rewards of smarties for each correct response.

The one further study, using Douglas' model, that has been identified from review of the literature, is that of Reed, Pien and Rothbart (1984) which has already been considered. They, however, used inhibition in a behavioural sense.

Methods of Study

With few exceptions, the studies reviewed reflect cross-sectional work. Hofstaetter's (1954) factor analytic study exemplifies an exception. Similarly, and except for the work of Piaget on a small number of children, and whose 'methode clinique' also defines partial exception to the distinction between naturalistic and laboratory studies, the vast majority of studies have used single tasks. Reed, Pien and Rothbart's (1984) work (reviewed on page 57) is a further exception in that four tasks were used. Using a cross-sectional design, the study demonstrated age-related differences in prevalent response tendencies in children, and the influence of temperamental and task specific variables in these.

Cross-sectional studies may not be an appropriate means of mapping developmental change, although Kendler (1977) has suggested a logarithmic method for predicting development and so obviating the necessity for longitudinal research. In support of this, she quoted Wohlwill (1973) that cross-sectional studies, using averaged data, do not necessarily describe the form of individual function, which may be saltatory or gradual. These statements are of particular relevance to the present study, since they were made in the context of studies of reversal and non-reversal shift. The latter has been argued by Kendler (1979) to be dependent on the development of selective secondary systems, which begin later than primary systems, and extend into adulthood. Kendler suggested that the secondary and higher level function may be partially activated before full maturity. Variables which influence the degree of activation, will include the nature of the stimulus, instructions, immediate training, motivation, and also individual differences. However, it is suggested that the use of mathematical models to describe aspects of ontogeny are valid only if these can be specified beforehand from prior knowledge of form and function. Clarke and Clarke (1984) have argued that assumption of constancy, within and between individual development, can be shown to be difficult to sustain. In support, they cite the recent results of Wedge and Essen (1982) from NCDS study that disadvantaged children at ages 11 and 16 were not necessarily the same children, and conclude from their review that both constancy and change are implicated in development. Kessen (1962) took the same view in a discussion of stage and structure in development Similarly, there are studies (e.g. Strauss 1982) which illustrate developmental anomalies in which older children's performance resembles or is poorer than that of much younger. Weir's (1964) work illustrates the point. A U-shaped curve appeared to describe his data, and he commented that although scores for older and younger appeared similar, the processes involved must be very different. It is, perhaps, the investigation of processes in child development that may elude the cross-sectional investigation, or the mathematically defined short cut alternative to longitudinal work. Whilst the problems of longitudinal work are well known, e.g. the possible effects on the individual of test-retest (Wohlwill 1973) and the risk of experimental mortality, there are many basic questions yet to be answered. One which is central to this research was discussed by Flavell (1972, 1977) on the emergence of strategies. These were considered as part of an analysis of Piaget's meta-theory. He conceptualised models of strategy evocation as addition, substitution, modification, inclusion and mediation. In an additive model, strategy Y added to X would provide an alternative means to a goal, whereas 'substitution' would imply that Y supersedes X, which would then be abandoned. Stabilisation of X or Y would occur in a modification model with practice of the skill, and a more advanced strategy e.g. Z, would be more readily evoked. An 'inclusion' model would provide for X to be included with other cognitive entities and form part of a larger unit of Y, and finally 'mediation' would imply that X acted as a bridge or facilitator for subsequent development of Y, which once established, became independent. Flavell considered that further, and process-oriented, research was needed to clarify strategy evocation and use. It is not clear how such questions can be approached except through longitudinal research, and in his review of the literature, Versey (1974) argued that the value outweighed the methodological pitfalls of repeated measures design. It is in the acceptance of advantages and disadvantages that the present study is longitudinal in design.

II LESION AND DEVELOPMENTAL STUDIES OF FRONTAL LOBES AND HIPPOCAMPUS

Introduction

The studies reviewed in Section I of this chapter, have suggested that a developing inhibitory ability underlies cognitive change and children's strategy use. This ability has been linked to maturation of functional activity in both the frontal lobes and the hippocampus. The literature to be reviewed in this section considers first, evidence from animal, human adults and children with frontal lobe lesion. Relevant behavioural studies and evidence suggesting development of the frontal lobes are also reviewed. Secondly, behavioural evidence of deficit following lesion to the hippocampus in animals and human adults is considered. The literature relating to post-natal development of the hippocampus in animals and humans is reviewed. Differences in behavioural deficit arising from differential lesion are drawn out, together with some methodological problems. These include an attempt to clarify conceptual confusions which arise from the attribution of localised function to specific brain areas. Finally, the correlational nature of the evidence is stressed.

Studies of cognitive deficit in animals following lesion to the fr ntal lobes

The classic studies of Harlow (1950, 1952 illustrate the substantial literature reporting attempts to analyse the nature of the deficits associated with frontal lobe lesions. Using a double dissociation technique, posterior (inferotemporal) lesions were compared with those with lesions of animals with anterior (bilateral frontal) area. Harlow (1952) noted greater impairment of frontally lesioned monkeys in learning a delayed response problem than did the 'posterior' groups, and who were impaired on visual discrimination learning. However, when procedures are made more complex, as in an oddity problem, the groups with frontal lesions showed as great a degree of visual discrimination impairment as the 'posterior' groups. The substantive finding has been that the kinds of error made differed qualitatively.

Frontally lesioned animals experienced great difficulty in overcoming spontaneous object preferences and aversions (Brush, Mishkin and Rosvold 1965). They extended the studies by Harlow (1952) to examine further the differences in deficit by animals with frontal, as distinct from temporal, lesions. Their subjects were 12 experimentally naive, immature rhesus monkeys. Four received surgical ablation of the entire dorsolateral convexity, four ablation of the temporal lobes except for the temporal pole, and four remained intact as a control group. All animals were trained, 10 days after the operation, on multiple object discrimination problems, single alternation and visual pattern discrimination, using the Wisconsin General Testing Apparatus. A detailed review is given since the study has been applied to child development by Lynn and Compton (1966) and has considerable relevance to the present investigation. For the multiple object discrimination problem, a pair of objects over food wells was presented. Two counterbalanced orders of presentation were used. In half the trials, both food wells were baited, and the object chosen was designated correct, but for the other half, neither object was baited, so that the chosen object was designated incorrect. The monkeys with temporal lesion were less successful than the frontal group on preliminary training and pattern discrimination (<.05). Training on single alternation, began after the animals reached the criterion. Both positions were baited, and the correct position was alternated until the animal made an error, when the bait was left in place until a correct response was made. Unlike the normal controls and temporally lesioned groups, the frontally lesioned monkeys failed to learn to criterion of 90 correct responses in 100 trials, or maximum of 1000 trials. Their impairment was marked by the high frequency of initial and perseverative errors. All groups made more reversal than non-reversal errors, but the reversal errors of the frontal group were significantly greater. An interesting point is that, whereas the clear tendency of the frontal animals to perseverate should have been an advantage in the non-reversal trials, this was not the case, since there was also a strong tendency to investigate new stimuli. The error types noted by Harlow (1950) of stimulus perseveration and response shift, similarly characterised the frontally lesioned animals (Brush, Mishkin and Rosvold 1965). This point is discussed further in relation to hippocampal lesions.

The problems experienced by frontally lesioned animals in learning a delayed alternation task were discussed further by Pribram, Plotkin, Anderson and Leong (1977). They attempted to analyse the differential nature of processing requirements in delayed alternation and delayed response tasks, arguing that, in delayed alternation tasks, spatial factors, although essential, serve primarily temporal and sequential aspects of the task. In contrast, although by definition, there is a temporal factor in a delayed response task, this serves primarily the spatial aspect. Two sources of evidence were given. First, the tendency of frontally lesioned animals to use strategies of lose-shift, win-stay at chance levels, and secondly, that manipulation of spatial factors has a weaker effect than of temporal in delayed alternation tasks. Pribram et al hypothesise that different effects might be found in temporarily or spatially organised tasks, which are dependent on functional localisation in the cortex, and therefore to location of lesion. Pribram's earlier work (1973) suggested that lesion to any part of the fronto-limbic system disrupts alternation behaviour, which is predominantly temporally organised. However, performance of monkeys is least disrupted when external cues, and therefore organisers, are available to reduce any uncertainty, and most disrupted when the organisation must be made by the animal. It is this internal organising ability which has led Pribram and Luria (1973), suggesting that the frontal lobes act as the executive of the brain; the 'planning' function suggesed in Miller, Galanter and Pribram's (1960) metaphoric description. Within an executive function, the frontal lobes act to inhibit response to potentially distracting qualities of, particularly spatial tasks.

However, in this review, it is suggested that any attempt to separate temporal from spatial factors is unlikely to be fruitful. While the temporal aspect of a delayed response task is undoubted, since the experimentor has manipulated the time delay, temporal constraint is implicitly present in a spatial task, since the consequent scanning occupies time in the information processing system. This point has been made when considering the four strategies which Inhelder and Piaget (1964 suggested are used in the development of a concept. Nevertheless, there may be additional cues in a spatial task which may alter the task demand on a subject, but interpretation of the direction of such demand is another matter. This point was made in Section I with reference to the work of Weir (1964) that the subject may not 'see' the task in the same way as does the experimenter. This is particularly relevant to studies of child development. For example, the young child's concept of 'same' appears to be one of identity, whereas an older child would also accept equivalence (Vurpillot and Ball 1979).

These differences in perspective between experimenter and subject are further highlighted by the attempts made by e.g. Pribram (1973) to localise CNS function. An apparent inability is found following frontal lobe lesion, to register novelty, so that events are reacted to as though a stimulus is novel at each successive presentation. This phenomenon appears, too, to be shown in work on maturation and function of the hippocampus, including studies of lesion. The apparent lack of response to novelty has been reviewed in Section I when considering the 'zero memory' model of Restle (1962) as an explanation of perseveration and alternation.

Similarly, and this will be discussed further in this section, the hippocampus has been viewed by O'Keefe and Nadel (1978) as a cognitive mapping system. Conceptually this links with Pribram's (1973, 1977) position concerning internal and external systems of organisation, and which he considered to be the synthesising function of the frontal lobes.

Pribram (1973) further argues that the frontal lobes are implicated in selective attention processes, and that the use of eye cameras to record visual search is relevant to the study of lesions in humans. The technique of photographing eye movement in cognitive developmental studies of selective attention has proved fruitful (Vurpillot 1968, 1979; Girgus 1976; Mackworth and Bruner 1970). Underlying Pribram's (1971) suggestions that eye cameras should be used, is his question concerning the relationship of attention to awareness and memory. In studies of human lesions to the frontal lobes, or to normal child development processes this is an important issue. Neisser and Beckler (1975), too, have argued that control over eye movements is consequential on 'selective attention'.

Behavioural effects of frontal lobe lesion in humans

The majority of studies in this area have considered cognitive deficits in adults. Milner (1964) compared 18 patients before and after frontal lobectomy with control groups with other cerebral lesions, temporal (N=33), parietal (N=8), pario-temporal occipital (N=5 , and orbital plus temporal (N=7). There was additionally a group of 23 patients who had suffered frontal lobectomy some years previously and were tested post-operationally only. All were considered to have atrophic lesions; surgical drawings of the extent of operated area were given by Milner (1964). The first test procedure used was the Wisconsin Card Sorting Test. This particular test has been used in the present investigation and by Vargha-Khadem (1983) and full details of administration and instructions to subjects are given in Chapter 3.

Milner's (1964) results indicated a substantial deficit in this task for the groups with frontal lobe lesion. Perseveration accounted for the majority of the errors ($p<.0001$) and was defined as repetition of a response which would have been correct in the immediately preceding stage of the test, or, in the first stage, as a repetition of an initial incorrect response. None of the control groups showed this tendency. Milner concluded that the frontal lobe deficit manifested itself as an inability to overcome a previously established response set, a finding which is consistent with those of animal lesion (e.g. Pribram et al 1977) and with human studies, reviewed by Milner. An interesting characteristic of the frontal lobectomised patients was their apparent inability to utilise information in active error reduction. Whilst expressing dismay at the increasing number of errors, their perseveration continued. In the discussion of Milner's (1964) paper, it was reported by participants that, in other studies, patients commented that they knew what to do, but could not do so. A dissociation was noted between knowing and doing; a finding which supported Milner's conclusions. This was attributed to a failure of verbal mediation, which Luria (1961) considered to be characteristic of frontal lobe lesion. Luria's contributions to the study of frontal lobe lesions are considered later in this section.

Milner (1964) administered a second task, which was intended to compare the non-verbal learning of patients with lesions to different areas of the brain. The task was a maze-learning test, in which nail-heads represented visible stepping stones. An error counter clicked audibly to inform patients of any departure from the correct path. Although the bilateral hippocampal lesioned patient showed more severe impairment than the frontally lesioned groups, who were, in turn, more impaired than all the other groups except the three with right posterior lesion, the error type differed. The frontally lesioned patients had a combined error score of 39.4 (range 13-70) (disregarding the rules for following the maze, $\bar{x}$=30.0 , and repetitive errors, $\bar{x}$=9.4). By contrast, the bilateral hippocampal group made a mean total of 0.7 errors (range 0-2) and all their errors were due to 'broken rules' and not to perseveration. However, there were three subjects only in this sub-group, and therefore, any generalisation is precluded concerning differences in deficit. Nevertheless, Milner's (1964) results, and the behaviour of the frontally lesioned patients' response to their difficulties in inhibiting incorrect responses, their distractibility and impulsive tendencies in the two tasks, demonstrate their inability to utilise cues and errors in active error reduction. These deficits in cognitive functioning following damage to the frontal system, have been described in detail by Luria (1961, 1973). He, too, identified perseveration as characterising adults with lesion to the frontal lobe system, together with a deficit in the ability to regulate behaviour by verbal means. Luria's discussion of verbal regulation of behaviour and the development of frontal lobe function in children is considered further.

<u>The function of the frontal lobes</u>

Luria considered with Pribram (1973) that the frontal lobes are concerned with the ability to maintain a set towards a goal, of an attitude of expectancy, and to maintain this in the face of interference until the expectation is confirmed or denied.

In the intact brain, Luria has argued that the frontal lobes, phylogenetically new in the brain, act as the third functional system, synthesising environmental information systems of stimuli and forming plans of action. Their function is to inhibit the activity of lower level brain systems, the first and second systems of limbic structures and reticular activating system, by means of its efferent output; as Pribram (1973) termed it, the executive function. The synthesis of environmental information include utilising cues from reinforcement as well as from non-reinforcement. However, the modification of behaviour, from non-reinforcement, is an aspect which has been linked to hippocampal function, and which is discussed later in this section.

Lesion appears to destroy ability, and the patient tends to perseverate. There is a difficulty of shifting response, and abnormalities are shown in responding to the consequences for action from the reinforcing properties of stimuli. In the animal literature, which has been reviewed, this presents as a distractibility, and spasmodic alternation may then be a further source of error (Pribram 1973).

The deficits appear not to be modal specific, and are shown in spatial, temporal or visually presented situations. They are particularly noticeable as the ambiguity of a task increases, (Pribram 1971) and it is suggested here that more time for processing is thus needed.

The lack of modality specificity associated with frontal lobe lesion is further borne out by Luria's clinical studies, and in a series of tests (Christensen 1975 , deficit in a wide range of motor, visual, language and conceptual functions, can be differentiated from those arising from lesion to other brain areas.

These deficits, identified in the animal and human lesion literature, can be summarised as inert behavioural stereotypes, and the inability to self-correct.

Frontal lobe lesion in children

The studies reviewed in this section have been of frontal lobe lesion in human adults and animals. In the case of children, the literature is sparse, but Vargha-Khadem (1983 has recently studied the effects of such lesion in children aged between 6 and 17 years, who were considered to be of normal intelligence. The sample consisted of 30 patients with left hemisphere lesion, 27 with right hemisphere lesion and 17 normal controls matched to the left hemisphere lesion group. Half of each lesioned group had suffered lesion pre-natally, and half post-natally, according to diagnosis by a neurologist. Considerable care appears to have been taken to identify subjects with unilateral lesion which was verified by computed tomography and rated blind by two radiologists. All subjects were tested on the Wisconsin Card Sorting Test, using the procedure fully described by Milner (1964) and given in Chapter 3 of the present study.
Mean perseverative error scores were as follows:

Normal control	= 15.76
pre-natal left hemisphere lesion	35.44
post-natal left hemisphere lesion	39.45
pre-natal right hemisphere	35.44
post-natal right hemisphere	30.64

From these figures, it can be seen that both left and right hemispheric lesion groups made substantially more perseverative errors than did the normal controls. This study was designed primarily to test the hypothesis that lesions sustained early in life, (i.e. pre-natally), would result in less deficit than those sustained later. This hypothesis would be consistent with studies (e.g. Goldman 1976) demonstrating plasticity in CNS systems. However, the error scores did not support the hypothesis. The interest for the present purpose here is the finding that the frontal systems of the normal controls were considered to have matured sufficiently for them to achieve a mean number of 4.35 (s.d. 1.93) of completed categories. Vargha-Khadem (1983) pointed out that the pre-frontal regions of the human brain are immature at birth from cyto and myeloarchitectural viewpoints.

Development of the frontal lobes in children

A major contribution has been made to the study of brain development by Conel (1951, 1955, 1959, 1963, 1967). He demonstrated extensively that association areas, including pre-frontal ones, are the latest to begin and complete myelination. Even by age 6, although there has been considerable development since age 4 years, including increase in quality and degree of differentiation of the chromophil substance to be found in all neurons in each layer of the cortical areas of the frontal lobes, development is not complete. One set of cells, the giant pyramidal Betz cells, appear most advanced, particularly those concerned with trunk and hand, but of those for the head, only 10.3% appear fully mature. Inferences from the available evidence are necessarily tentative. The number of subjects studied has been small, and their availability limited to children who have died from accident or disease, e.g. leukaemia. Tanner's (1961 studies indicated individual differences in aspects of cortical myelination, apart from those of skeletal or maturation of secondary sex characteristics and activity. Nevertheless, the inference can be made from Conel's work (1967) that full frontal lobe function is unlikely by age 6.

This is a more cautious view than one quoted by White (1975) of Esther Milner as suggesting from her review of cortical maturation that this was complete by age 6. To her is attributed the quotable suggestion that at this age, the 'human principle' comes to be dominant over the 'mammalian principle'. The significance of the statement is the possible link with developing inhibitory processes, including that of the role of verbal mediation, which was discussed in Section I. The evidence from Conel's work (1967) and from Vargha-Khadem's (1983) behavioural study is largely consistent with Luria's (1973) graphical representation of the surface area of the frontal lobes, and rate of cellular myelination in the frontal cortex which show rapid increase around 3½-4 years, with a further jump at 7 years (Fig. 2). Luria considered that the frontal lobes become prepared for action between 4 and 7 years. It is worthy of note that this period co-incides with the progressive disembedding from the perceptually immediate, which Piaget (1964) considered to be the achievement of the intuitive sub-stage.

Figure 2 Rate of increase in the surface area of frontal lobes and rate of maturation of cells in the frontal cortex

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[redacted]

Figure 17 Rate of increase in area of the frontal lobes and rate of increase in size of nerve cells in ontogeny (after Moscow Brain Institute)

from A R Luria, 1973, <u>The Working Brain</u>, Penguin

This graph, particularly the curve for rate of increase in the surface of the frontal lobes, is seen as very similar to the curve yielded by Hofstaetter's (1954) factor analytic study (Figure 1). Hofstaetter's results were reviewed in the first section of this chapter, together with White's (1965) review of the development of planning abilities. These were argued to be evidence for an inhibitory ability which becomes functional between 5 and 7 years.

The correlation between frontal lobe lesion studies and aspects of child development

A direct attempt was made by Lynn and Compton (1966) to link behavioural effects of lesion in monkeys to normally occurring behaviour in children. The subjects were 16 children aged between 3.0-4.7 years and 6 young adults aged 18-19 years. The procedure used was adapted from that of Brush, Mishkin and Rosvold (1965) which was reviewed on page 80 of this chapter. Two experiments were carried out. The first, a Two-Choice Discrimination Learning Task, using reversal and non-reversal conditions, is fully described in chapter 3, since it is used in the present investigation. Results showed that mean errors on the reversal condition (5.75) exceeded those of the non-reversal (2.93), and that this difference was significant at $P<.01$. There was no significant difference between conditions for the adult group.

In a second experiment, a preferred response was induced by training in which only one beaker was presented. A second beaker was added, and in one condition the first beaker continued to be correct for 15 trials. In the second condition, the additional beaker became correct, enforcing a reversal of choice. Subjects were tested in both conditions in counter-balanced order. Results were highly significant ($p<.005$). The second condition produced a mean error of 5.25 compared with 0.80 for the first. From the results of the two experiments, Lynn and Compton (1966) concluded that children, but not adults, resemble frontally damaged monkeys in their perseveration difficulty in overcoming a reinforced response in order to substitute another. They attributed the perseveration difficulty to an absence of internal inhibition, which was argued to be the function of the frontal lobes. From this, Lynn and Compton (1966) further concluded that immaturity of development of the frontal lobes in children is the most plausible explanation of the similarity between the children and lesioned animals. This was coupled with other similarities of hyperactivity and distractibility, and of EEG evidence from Lindsley (1960) that frontal systems are not fully mature until about 12 years.

The parallel is drawn between the evidence reviewed by Lynn and Compton, and the work of Conel (1951, 1955, 1959, 1963, 1967). While Conel's atlases of the brain do not extend to age 12, the immaturity noted at 6 years, would indicate a much later age of full maturity. This may link with the work of Tomlinson - Keasey, Kelly and Barton (1978) who presented pictorial or symbolic stimuli singly, to either the right or left hemifield in children of mean age 8.8 years and 12.3 years, and to adults 27.9 years. On the basis of their experiment, they concluded that full function of the left hemifield was not attained until adolescence.

Methodological issues

However, the work cited simply serves to identify the problems of attempting to be age-specific or location specific, concerning CNS functions. Evidence which indicates similarities between normal processes in child development with lesion in adults or animals, is at best correlational. In animal studies, in particular, the possibility of diaschisis, or suppression of normal functions following surgery, does not seem to have been considered (St James Roberts 1981). Luria (1973) commented that localisation of lesion need not pre-suppose localisation of function, and that the lesioned area should be regarded as interference with a system.

This point was cogently made by Gale (1980) in a critique of 'naive parallisms' although Gray (1980) in the discussion of Gale's paper, argued that sophisticated modern techniques for brain study do allow inferences to be made from behaviour to specific brain events. One such non-surgical technique is cryogenesis in which specific areas are frozen, and in which normal function is temporarily suppressed. Goldman (1976) refers to this technique in her review of deficits following early and later lesioning and which support, in general, findings from surgical interference.

Gray (1975 has elsewhere argued that it is possible to map from a 'conceptual nervous system' to the 'real nervous system'. However, it is not at all clear that the conceptual nervous system is well understood. For example, Lynn and Compton (1966) conceptualised their experiment within a Pavlovian model of internal inhibition, and attributed this to frontal lobe function. Internal inhibition, however, has substance only at the level of a construct, and, in so far as it may prove to be conceptually sound, has also been attributed to hippocampal function (Douglas 1972, 1975; Isaacson and Wickelgren (1962; Isaacson 1972).

Animal studies of the links between the hippocampus and internal inhibition

Internal inhibition was defined in Section I as the active suppression of response following non-reinforcement. Behavioural evidence (Isaacson and Wickelgren 1962; Altman and Bayer 1975; Fredrickson and Fredrickson 1979a

1979b; Douglas 1972, 1975) has been used to suggest that the hippocampus has internal inhibitory function. Its maturation in particular species appears to be differentially related to position on the phylogenetic scale, and function to be susceptible to lesion of the hippocampal structure. Douglas (1972, 1975) presented evidence to support parallels between loss of internal inhibition following lesion and normal processes in child development. Studies of child development attempting to test the theory have been reviewed (Clayfield 1976; Reed, Pien and Rothbart 1984).

Much of the evidence in animal learning studies centres around the phenomenon of spontaneous alternation, which is considered to be a mammalian tendency to avoid stimulus re-exposure during investigatory or exploratory behaviour. In a Hullian framework, the concept of reactive inhibition would predict that a rat would alternate his turning responses, whereas in that of Pavlov, alternation of alleys visited would be predicted under a model of internal inhibition (Douglas 1972). Glanzer (1953) conceptualised spontaneous alternation as 'stimulus satiation', when, for instance, the visited alley loses much of its stimulus strength, because of the generation of stimulus-specific inhibition. In other words, it is a case of orienting followed by non-reinforcement. As was reviewed in the writer's MA study (1976), Douglas (1972) inferred from his studies, and those of others, that non-reinforcement activates the hippocampal circuitry to inhibit an excitatory reaction by the reticular core to sensory input, when a subject then ignores an unreinforced stimulus. The term 'ignore' is used rather than 'avoid' which carries quite different implications, and links well with Glanzer's (1953) argument that spontaneous alternation is concerned with choice rather than response He also suggested that spontaneous alternation is a pure form of habituation, unaffected by low levels of arousal due to such as fatigue.

Spontaneous alternation

The significance of spontaneous alternation, as reflecting internal inhibition, to the question of active function of the hippocampus, is that it appears to have a sudden onset at about 4 weeks of age in the rat. Before 4 weeks the dominant response appears to be perseveration, or the stereotyped repetition of a response. Douglas (1972) reviewed literature which suggested that this period also corresponds to the levelling out of differentiation of dentate gyrus granule cells. In the guinea pig, whose hippocampus appears to be well developed at birth, spontaneous alternation at an adult rate is present by 10 days. Further evidence to suggest post-natal development of the hippocampus is reviewed later in this chapter.

In the two studies of the emergence of spontaneous alternation in the kitten, Frederickson and Frederickson (1979a, 1979b) showed parallels between the repetition behaviour and reduced exploratory tendencies in a variety of species exposed to hippocampectomy, and the behaviour of kittens. In the first study (1979a) two experiments were carried out, one using 55 kittens aged 21, 28 and 35 days, in small and also large T mazes, with a further 63 naive kittens 28, 30, 42 and 49 days old in a third T maze. Care was taken to eliminate any source of cue; light leaks, paint spots or smell. In a second experiment 28 day old (N=22) and 42 day old naive kittens (N=12) were tested in a modified enclosed T maze with both goal arms visually discriminable. Results indicated age-related increase in alternation, which was necessary in order to complete the maze. Whereas 92% of the adult cats completed the maze within the 10 minute criterion time, 71% of kittens at 4 week old, 93% of 5 week old 89% of 6 week old and 78% of 7 week old kittens did so. None of the 3 week old kittens were successful.

It is of interest to the investigation to note that alternation behaviour peaked at 5 weeks, and then declined. This suggests the emergence of complex patterns of response, and which are also noted in children. Further analysis of turning behaviour indicated that alternation at 3 weeks (43%) and 4 weeks (52%) was at chance level, but at 5 weeks (85%), 7 weeks (92%), and adult (100%) alternations were significantly above chance ($p<.05$). Analysis of alternations of 3 and 4 week old kittens showed significantly lower proportions than each of the older groups ($p<.025$ for difference of proportions) whereas no other differences between groups were statistically significant. Very similar findings were shown in Frederickson and Frederickson (1979b) study of open-field behaviour in kittens at 3, 4, 5, 6 & 7 weeks. Increase in loco-motor exploration was age related with significant differences between 3 and 4 week old kittens compared to 5, 6 and 7 week olds.

As the converse of development in animals, where the hippocampus has been destroyed or bilaterally lesioned, although alternating responses can be learned with the use of reinforcement, the spontaneous aspect has gone. Douglas (1975) stressed that this is specific to lesions of the hippocampal system, and that lesions to other parts of the limbic system or neocortex do not have the same effect.

Passive avoidance behaviour

Douglas' (1972, 1975) research centred mainly on spontaneous alternation as a behavioural index of internal inhibition, dependent on a mature and intact hippocampus. His review of literature suggested that, like spontaneous alternation, passive avoidance learning can also be shown to increase dramatically at about one month of age in the rat. Passive avoidance is defined by Gray (1975) as the decrease in the probability of a response previously rewarded and subsequently punished. As a phenomenon, it appears to combine both instrumental and classical aspects of conditioning (Gray 1975), which have been argued to undergo changes in children's learning of these between 5 and 7 years (White 1965).

As an example of behaviour dependent on internal inhibition, passive avoidance is not only in a different category to active avoidance, which appears to be excitatory, but can be shown to be more difficult to teach to hippocampectomised rats (Douglas 1972). The evidence for this is drawn from Isaacson and Wickelgren (1962), who showed in a study of 6 rats with hippocampal lesions and 6 with neo-cortical lesions, that hippocampectomised rats failed to learn a passive avoidance task using a shuttle box. Their latencies were shorter, and post-shock effects were slight and transient, compared to the longer latencies, and post-shock effects for rats with neo-cortical lesion, and who would not re-enter the shuttle box for at least three post shock trials. The experimental paradigm is not easily tested in child development study, and the difficulties of attempting to do so have been reviewed in the first section (Clayfield 1976).

Differences between effects of lesion to the hippocampus and to the amygdala

The difference between hippocampectomised animals and those with other neo-cortical lesions, including those of the amygdala appears to lie in the use of reinforcement. Whereas animals with hippocampal lesions show marked deficit in learning tasks with negative i.e. non-reinforced instances, amygdalectomised animals learn as quickly as do normal (Douglas 1972). The deficit appears to be in a failure to utilise errors and, as was suggested from Frederickson and Frederickson's studies on kittens (1979a, 1979b) it has been inferred that hippocampectomised animals do not seek novelty as do normal. By contrast, amygdalectomised animals appear to over-react to novelty. This characteristic supports a view of the amygdala as predominantly excitatory, with the function of allowing experience to be appropriately registered; an internal rehearsal (Pribram 1971). In the writer's view, both the inhibitory activity of hippocampus and excitatory activity of amygdala can be argued to be part of Bruner's (1974) postulated neural gating mechanism, which he suggested underlay acts of categorisation. Damage to either structure is likely to lead to stereotyped responding. This can be of perseveration due to reduced exploratory behaviour, following hippocampectomy, or alternation from over-reaction to novelty, following amygdalectomy. The writer suggests that, other than in the experimental situation, where the conditions for learning are manipulated in order to determine effects of a specific lesion, learning would seem to depend on intact systems. Inhibition and excitation would thus mutually antagonise and induce each other. This point would be supported by Douglas (1972). Perseveration and alternation are as has been discussed, noted in frontal lobe lesion, and so far from these being characteristic specific to such lesion, may result from, as Gale (1980) noted, interference with a system. Nevertheless, there does appear to be evidence that the hippocampus has a substantially inhibitory function, and Douglas (1972, 1975) would argue from application of Pavlovian theory, that this is internal, or stimulus - specific, inhibition. As such, it is considered to be distinguishable from external, or non-specific, inhibition. The concept of internal inhibition is supported by Gray (1975), Konorski 1972, and Hearst (1972). Hearst discussed in some detail problems of definition of conditioned inhibition, which he argued was close to his concept of internal inhibition, and also the methodological weaknesses of many previous studies. He contends that evidence would not support a concept of inhibition as 'the weak sister of excitation'. Hearst's view is supported by Gray (1975) who reviewed the literature in considerable detail. The behavioural evidence is supported by physiological studies of neuronal inter-connections and neuro-transmitter activity. These link the hippocampus to inhibitory activity.

Neuro-physiological studies

Andersen (1967) noted that all investigations, using intracellular recording in the mammalian hippocampus, had found hyperpolarisation, indicating inhibition of cell discharge, following excitation of the cell, from all afferent sources studied to that date. He cited the early evidence from Cajal (1911) and from his own work to suggest that the basket cells function as inter-neurons to inhibit activity of the dentate cell body. This interpretation is supported by one recent and detailed analysis of the anatomy and physiology of the hippocampus (O'Keefe and Nadel 1978). In support of their conceptualisation of a cognitive map, O'Keefe and Nadel discussed the neural pathways to the hippocampus, and which appear to be concerned with the inhibitory neuro-transmitters of serotonin and nor-adrenaline. Additionally, O'Keefe and Nadel cite studies suggesting wide-spread cholinergic input to dorsal and ventral hippocampus. Stimulation of the system appears to facilitate the release of acetyl-cholinesterase. The review by Warburton (1972) of drug-related cholinergic activity, linked this to internal inhibitory function.

Current interest in drug models of behaviour, and of the role of neurotransmitters in memory and learning, add to the growing body of evidence of the importance of the hippocampus. Douglas (1972) had earlier suggested that the hippocampus is essentially cholinergic. He further stated that the administration of anti-cholinergic drugs, such as scopolamine, abolishes spontaneous alternation, and both one-way and two-way passive avoidance learning. Conversely, drugs which potentiate cholinergic activity also potentiate theta waves of 4-7 cps, as does serotonin. Theta waves have been associated with hippocampal activity (Douglas 1972). Similarly, from a developmental point of view, Altman and Bayer (1975) reported low levels of acetyl-cholinesterase in the 3 day old rat hippocampus. This increased to adult levels of distribution and intensity by 35 days of age.

The parallel is drawn between this evidence and the hypothesis of Rosenthal and Allen (1978) that hyperkinetic behaviour can be linked to fore-brain immaturity. Their work was reviewed in the first section of this chapter.

Parallels with development of human hippocampal activity

The increase in levels of acetyl-cholinesterase (ACHE) in young rats from day 3 to day 35 (Altman and Bayer 1975) appears to be paralleled by the increase in spontaneous alternation in a variety of mammals e.g. Frederickson and Frederickson (1979a, 1979b). Altman and Bayer further demonstrated that in rats and mice, there is post-natal migration of cerebellar granular cells which synapse with mossy fibres. Douglas cited Altman and Bayer's work in support of his hypothesis that internal inhibition develops with maturation of the hippocampus, and is lost when bilateral lesion or ablation is performed. His arguments hinge on the research evidence that, contrary to previous thinking, the hippocampus is not only not functioning at birth in several species, but is structurally incomplete.

In the rat, there can be shown to be increased mitosis at about 10 days of age with migration of neuron cells to the dentate gyrus of the hippocampus. There also appears to be further differentiation through growth of axons and dendrites (Altman and Bayer 1975). Where there is experimental prevention of acquisition of post-natally forming hippocampal granule cells, animals behave as do those where there has been surgical destruction of the hippocampus.

To establish that there is considerable post natal structural development of the hippocampus in rats or mice is not to say that this is universal across species, and in the guinea pig, migration of neuron cells appears to be complete at birth. Still less is it possible to make comparison with man, and from the available evidence on human hippocampal development (Humphrey 1967) it appears that, at 30 weeks, the foetal hippocampus closely resembles the adult structure.

Development of the hippocampus in children

Conel's (1951, 1955, 1959, 1963, 1967) careful mapping of the human brain has similarly provided evidence that the complement of neurons is complete at birth. However, in comparing brains of 24 month infants with those of 4 year olds, Conel (1963) showed that growth had occurred in the size of cells, that dendrites were longer and larger, and that there was more myelination in all cortical areas, including that of the hippocampus. Rather less detail of hippocampal development is given in his description of 6 year old brains (1967). Dendrites are larger and more compact, but not longer or more than for 4 year olds. Myelination in all areas had increased, but was not complete. The most advanced areas at 6 years appear to be the primary motor and sensory areas. In view of the considerable amount of detail given by Conel (1963), the question can be asked whether the reduced amount of information about hippocampal development (1967) implies a slowing of rate of development between 4 and 6 years.

If this is the case, then some additional support is given to Douglas' (1972, 1975) argument that the sudden onset of internal inhibitory ability, manifested by spontaneous alternation at around 4 years is the result of hippocampal maturation. The cross-sectional studies reviewed have shown that children spontaneously alternate in binary choice tasks from 4 years old (Frith 1970a 1970b; Douglas 1976; Clayfield 1976; Reed, Pien and

Rothbart 1984).

Concluding comments

It appears, from the literature reviewed, that spontaneous alternation is but one index of important behavioural changes which have been suggested as indicative of inhibitory ability. This has been correlated, from the review of literature, with maturation of function of both the hippocampus and of the frontal lobes. It is suggested, from this, that the apparent contradictions shown by the review of, in particular, the lesion literature, support a concept of the development of an inhibitory system, in which both hippocampus and frontal lobes are implicated. Luria's (1973) and subsequently Gale's (1980) argument that the effects of localised lesion interfere with a system, are relevant.

From the review of literature, the aims of the present study have been formulated, and fully described in the next chapter.

CHAPTER 2

AIMS OF THE STUDY

The review of the literature has shown aspects of advances in children's problem-solving abilities from about 4 years of age. The term problem-solving abilities subsumes a variety of cognitive tasks, including the use of strategies to organise recall, the ability to regulate behaviour by means of language, selective attention in visual scanning, and the ability to utilise selectively cues and errors in hypothesis formation and testing in discrimination learning. The child's cognitive behaviour gradually approximates that of the adult. Incorporated within this development, would be the more reflective tempo which supersedes the impulsive mode of the young child, although individual differences, and the nature of the cognitive demand, exert influences. The literature suggests that earlier modes of behaviour may not be lost, but are inhibited by more advanced organisation of behaviour, which can be summarised as planning behaviour. In previous work the writer (1976) investigated the possibility of the development of internal inhibition as the necessary and sufficient condition for more advanced cognitive organisation, using a cross-sectional design. In the work, evidence was found to support the results of neuro-psychological studies, particularly those of Douglas (1972, 1975, 1976). More specifically, it appeared that rigidly stereotyped choices and responses of perseveration by 3-4 year olds were replaced from 4 years by alternation of choice or response, and subsequently by more complex patterns in a Spontaneous Alternation task. These appeared to find parallels in the development of logical reasoning, as in a multiplicative classification task (Inhelder & Piaget 1964).

There were, however, questions raised from the results which indicated that over 4 years of age, a child whose dominant response in one task was to alternate, would perseverate in another. Whilst, in general, there was support for the major hypothesis that internal inhibitory functions mature around 4 years of age, it was clear that further investigation was necessary. In particular, and from extensive search of the literature, although there is evidence that an ability, termed inhibitory, does appear to be developing during childhood, it is not clear whether, once functional, it is utilised in all problem-solving situations. Further, the literature would suggest that a hypothetical inhibitory function might itself undergo further change, and differentially influence problem-solving performance. This possibility underlies the studies of frontal lobe lesion and development in humans and infra-human species, similarly, those of the hippocampus, together with aspects of child development, which have been reviewed.

From these, it would appear that perseveration represents a pre-inhibitory strategy and that an alternation strategy may signal the onset of inhibitory ability, but with initially limited potential for the utilisation of cues and errors as a necessary condition for planning problem-solving behaviour. That changes in strategy use occur is clear, but the nature and significance of these is not. Flavell's (1972, 1977) questions on the emergence of strategy availability and use, seem central, and are discussed on p78 of Chapter 1.

The studies reviewed, with the one exception of Hofstaetter's (1954), and which suggest that perseveration and alternation represent limited strategies for exploring relevant dimensions of a given environment, have been cross-sectional. No work appears to have been carried out on the emergence and utilisation of strategies by children in a variety of problem-solving tasks. Neither do there appear to have been studies of the relation-ships between strategies. For example, once an alternation strategy appears in the child's repertoire, it is not clear whether this constitutes an additional competence, substitutes for perseveration, combines with it, or is included, subsequently to be modified and elaborated.

In the present research, the interest is in age-related changes in strategy availability and use, strategy being defined as a behavioural competence for testing an hypothesis about a pattern rule. A necessary condition for extraction of a pattern rule, through hypothesis testing, is the utilisation of cues and errors. The literature reviewed suggests that development of inhibitory abilities is the enabling process for active error reduction, and the present study aims to investigate the behavioural evidence for this in children, aged between 3-9 years.

The major intention of the present investigation is to explore processes, and it is suggested that to describe age-related changes, within as well as between children, is a necessary pre-condition for subsequent attempts at explanation and fuller understanding of cognitive development.

A longitudinal study, utilising a repeated measure design, is considered to be an appropriate method for investigation of these questions. The use of overlapping age samples, each of which is studied over a two year period, enabled a six year span of development to be studied, by results from the administration of a battery of six tasks. Further, the design reduces some of the risks from experimental mortality, a hazard of longitudinal research. Full details of the design, tasks and sampling procedures are given in Chapter 3.

The form of the data derived from the six tasks, Wisconsin Card Sorting Test, Spontaneous Alternation, Oddity Problem, 2 choice Discrimination Learning, 3 choice Discrimination Learning, and Attributes Task, allows a variety of transformations, based on error analysis, to be carried out to test the main and secondary hypotheses. Each of the tasks, with the exception of Spontaneous Alternation, which is unpatterned, and thus allows for the imposition of it by the child of a dominant strategy, defines a range of patterned problems, from which the solution rule can be extracted, through active error reduction.

The null hypotheses to be tested, and for which the .05 level of significance is considered sufficient for rejection are that:

There will be no significant differences

1. between age groups of children in numbers of perseverative errors made on the Wisconsin Card Sorting Test;

2. within children at each testing on numbers of perseverative errors made on the Wisconsin Card Sorting Test;

3. between age groups of children's use of dominant response tendency (strategy) on the Spontaneous Alternation Tasks;

4. within children at each testing of use of dominant response tendency (strategy) on the Spontaneous Alternation Task;

5. between age groups of children in number of perseverative errors made in the Oddity Problem;

6. within children at each testing in number of perseverative errors made on the Oddity Problem;

7. between age groups of children in number of perseverative errors made on 2 choice Discrimination of perseverative errors made on the 2 choice Discrimination Learning Task;

8. within children at each testing on numbers of perseverative errors made on the 2 choice Discrimination Learning Task;

9. between age groups of children in number of perseverative errors made on the 3 choice Discrimination Learning Task;

10. within children at each testing on numbers of perseverative errors made on the 3 choice Discrimination Learning Task;

11. between age groups of children in numbers of perseverative errors made on the Attributes Task;

12. within children in numbers of perseveration errors made on the Attributes Task

and

There will be no significant correlation

13. between perseverative error scores on any of the tasks administered, on each of the 4 test occasions;

14. there will be no significant correlation between age and perseverative error scores from each of the tasks administered on each of the 4 test occasions.
Statistical techniques for testing the null hypotheses stated include Analysis of Variance, Trend Analysis, and Principal Components Factor Analysis, using perseverative error scores as the dependent variable,

and perseverations in the case of the Spontaneous Alternation Task. Additionally, Arc-Sine Transformations of perseverations to total errors or trials are used for further Analysis of Variance and Trend Analysis.

Subsidiary hypotheses are additionally derived, and which may provide further evidence for investigation into functional maturation of central inhibitory systems as well as the relationship of sex and social status to error behaviour. These are stated in the null form and tested by appropriate parametric and non-parametric statistical techniques. The .05 level of significance is considered sufficient for rejection of a null hypothesis.

There will be no significant differences

i between children at each age level in number of perseverative errors made in attaining 3 categories in the Wisconsin Card Sorting Test;

ii between children at each age level in number of trials taken to reach criterion in 3 categories in the Wisconsin Card Sorting Test;

iii within children at each of 4 test occasions in number of trials taken to reach criterion in 3 categories on the Wisconsin Card Sorting Test;

iv between children at each age level in ease of making a reversal shift in the Two-Choice Discrimination Learning Task;

v within children on each of 4 test occasions in ease of making a reversal shift in the Two-Choice Discrimination Learning Task;

vi between the sexes in number of perseverative errors made on any of the 6 tasks;

vii between socio-economic status groups in number of perseverative errors made in any of the 6 tasks;

and

viii there will be no significant correlation between scores from pre-tests (Ravens Coloured Progressive Matrices, Reynell Language Comprehension Sub-scale, and Matching Familiar Figures) and scores obtained from each or any of the 6 experimental tasks.

CHAPTER 3

DESIGN OF THE MAIN STUDY

Introduction

A pilot study (Appendix 1) was carried out, prior to designing the main experimental study. This yielded a considerable amount of information on children's problem-solving behaviour in a variety of experimental situations, and further enabled the refinement of methodology and task procedures for incorporation into the main study. In particular, criteria were defined for inclusion of a task within the main experimental task battery. These were:

a) the task should be appropriately used in a repeated measures design in which each subject would be tested on 4 equal interval occasions on the same tasks over a 2 year period;

b) the task should be given to children as young as 3 years, as well as to those up to, and including, 9 years old;

c) the task should either have been used in the pilot study, or have been fully described in literature relevant to the investigation;

d) the task should yield data which could be used for purposes of error analysis, since the use of strategies in active reduction of error is of central concern;

e) scoring should be unambiguous and objective. For one task, Wisconsin . Card Sorting Test, this necessitated carrying out a reliability study on a sample of the data. This is fully reported as Appendix 5.

f) the task should be easy to administer, and repeatable on 4 occasions without risk of error.

All tasks finally selected, and which are fully described in this chapter, were tried out on a further 10 children of the target ages from the pilot study school, in order to practise procedures and instructions for the tasks. On one occasion, a co-scorer independently recorded the subject's responses.

Implications from the Review of Literature for the tasks to be used within the study

The review of the literature has supported the argument that the mapping of development of the availability, and use by children, of problem-solving strategies, necessitates study over time. A repeated measure design has therefore been constructed to enable age-related developmental changes in such strategies to be identified from a range of tasks, during a two year period for each child. From the literature, from previous work by the writer (1976), and from a pilot study carried out in 1979 for this research, six experimental tasks have been identified, which have construct validity for the hypotheses under test. These, together with pre-tests used, are described as follows.

Pre-tests

Three pre-tests, Coloured Progressive Matrices (Raven, Court and Raven 1977), verbal Comprehension of Language (Comprehension Sub-Scale) (Reynell 1977) and Matching Familiar Figures (Kagan et al 1964) were administered to each child individually. These were selected for their ability to yield measures of non-verbal intelligence (RCPM), comprehension of language (Verbal Comprehension Sub-scale), and reflective-impulsive dimension of conceptual tempo (MFF). The rationale for the choice of pre-tests is given.

Coloured Progressive Matrices (RCPM)

This test has a wide application in psychological, educational and clinical research. It is considered to test qualitative aspects of intellectual development, from the ability to distinguish identical figures from different ones, to similar from dissimilar, and therefore fit a pattern piece into a matrix, to the later conceptual ability to conceive of pieces as a spatially related whole, and to reason by analogy. It has been selected because of its established reliability and validity, and for ease of administration (Anastasi 1982), although the matrices have not been standardised in children younger than 5 years. Norms for ages 3½-5 years are extrapolations, and no norms are available for those children below 3½ years. Nevertheless, three year old children can fit pattern pieces into the matrix and the use of raw scores is considered sufficient for the purpose of comparison with other pre-test results.

Reynell Verbal - Comprehension Sub-scale

The Reynell Verbal Comprehension Sub-scale tests aspects of language comprehension from the first verbal pre-concepts to an ability to relate together a large number of verbal concepts, and use ideational content of language. In order to achieve a high score on the sub-scale, virtually every word must be understood, which might have implications for more general information processing abilities. It has been standardised on children whose mother tongue is English, and aged 1½ years to 7 years. The task therefore covers the age span of the children in this study. Standard scores are available for use in analysis in addition, to raw scores. It has been noted that split-half reliability co-efficients between short and long versions during the revision of the scales are highest in the middle range, but nevertheless, item analysis enabled the inclusion of only items with a high co-efficient of discriminability (Reynell 1977).

Both non-verbal intelligence and language comprehension abilities were deemed to be necessary measures. In part, their inclusion enabled the experimenter to ensure that the target children came within the normal range for these abilities. The major reason for including non-verbal intelligence and language abilities lay in their implications for the research, e.g. to what extent is language cause, or correlate, of inhibitory ability.

Matching Familiar Figures

This test was developed by Kagan et al (1964) to measure the impulsive-reflective dimension of conceptual tempo. He considered that this construct reflected age-related development, and individual differences of personality. The two measures obtained from the test are mean number of errors made in matching a standard picture to the identical one from a set of 6 variations, and the latency time before responding. In general terms, there is a tendency over age to make fewer errors, to take longer before responding, and which is indicative of a reflective trend.* Since the development processes involved in reduction of errors are substantive issues of the research, a decision was made to include the test as a pre-test, for purposes of comparison with the task battery. It would appear to have construct validity with the developmental trend from impulsivity to reflectivity, and therefore implication for the development of inhibitory function.

Administration of Pre-tests

Each of these tests was individually administered according to the procedures given in the test maruals. The board form of RCPM was used for all age groups, for the purpose of consistency.

Experimental Task Battery

The rationale for the use of each task used in the main study is given. Full details of the procedures and materials for administration of the tasks are given on pages 135-144 of this chapter.

* It may be noted that Badger (1979) made adverse criticism in her Ph.D. study regarding the construct validity and reliability of Matching Familiar Figures Test as a measure of reflection-impulsivity. However, she was concerned with the 'trade-off' between time taken before responding and error behaviour, and her conclusions are not central to the present investigation.

<u>Wisconsin Card Sorting Test (WCST)</u>

This test requires a subject to sort cards by categories, colour, form, or number. To sort successfully, the subject must extract the relevant feature of the stimulus cards, and ignore the irrelevant. It further requires the subject to shift 'attention' from previously correct but newly incorrect features in order to sort to further categories. Hypothesis theory (Levine 1966) would state this as that the subject forms an hypothesis that e.g. colour is correct, and then tests the hypothesis by sorting to colour until this is refuted. Information of 'right' or 'wrong' is given to each sort, and allows the subject to achieve the appropriate hypothesis by active error reduction.

Essentially the WCST is a test of ability to abstract concepts or categories, and is considered by Milner (1964), see page 86, and by co-workers in the field of frontal lobe lesion studies to be sensitive to impairments resulting from frontal lobe as distinct from other cortical lesion. Although the findings may not be analogous to the normal processes occurring in child development, it was nevertheless thought to be a useful task to include in this study because the ability to categorise and to utilise information of right or wrong are central to cognitive development. The test offered a means of eliciting changes in hypothesis testing strategies used by the target age groups, 3 to 9 years.

A modification to the size of the card pack used was made. Milner (1964) used 128 cards, which varied along the dimensions of colour, form and number. Her pack contained 64 different cards, and each of these was duplicated. For the purposes of the study, half the pack, and therefore 64 different cards have been used. Since the subjects in the present study were each being tested on a battery of 6 experimental tasks, were young children, and testing time was constrained by the school's timetables, it was considered preferable to use a reduced pack. The need to avoid the risk of fatigue to the children from prolonged test sessions was an important consideration.

Spontaneous Alternation

This task is a modification of the card test used by Frith (1970) and has been used by Clayfield (1976) and in a pilot study for the present research (1979). As reviewed in Chapter 1, it requires the spontaneous production of binary sequences, which is thought to generate spontaneous alternation in children; a phenomenon which Douglas (1972, 1975) considered to indicate the development of an internal inhibitory ability (see page 70 It is considered to be analogous to the blank trial procedure used by Gholson, Levine and Phillips (1972) as a means of eliciting the dominant hypothesis applied in an attributes task, and which indicated that response sets of position perseveration, alternation (single, double and 'residual') persisted at 2nd and 4th grade levels, rather than identifiable hypotheses of focussing or dimension checking (see page 38). The major and important difference between the Spontaneous Alternation task and that of Gholson, Levine and Phillips' blank trial procedure is the number of dimensions used. They used eight, and this implies that their task was more complex.

Oddity Problem

As is reviewed in Chapter 1, page 80 this task represents a special case of a learning set, and was originally used by Harlow (1949, 1951) who considered it sensitive to frontal lobe lesion in animals. He noted that solution of an oddity problem, requires that position preferences, perseveration and alternation error strategies be overcome. From trial and error, the rule of solution is abstracted from discrimination learning and is demonstrated by transfer to further oddity problems. Transfer to further oddity problems implies an ability to make a reversal, and ease in doing so increases with ascent of the phylogenetic scale, and over age in children. A version of the oddity problem was considered useful for inclusion in this research. Sufficient data exists from the published literature for comparison to be made, and the task appears to have value for eliciting the use of strategies, and the ability to inhibit errors as a result of non-reinforcement.

The procedure followed is fully described in the Procedure section, p138 , and replicated that of Lunzer (1968) except that a maximum of 10 rather than 20 problems was given to each subject. As with the Wisconsin Card Sorting Test, fatigue, and possibly boredom, for younger children were criteria for reducing task length. Lunzer's second and third stages were included for all those who learn the problem. The requirement for a verbal justification of the solution rule, was included to illuminate the role of language in problem-solving.

Two-Choice Visual Discrimination Learning

This task, originally developed by Brush, Mishkin and Rosvold (1965) for use with monkeys, and subsequently adapted by Lynn and Compton (1966) in an experiment with children. has been reviewed in Chapter 1. It has been used in the pilot study of the present investigation (Appendix 1), using a repeated order of presentation of non-reversal and reversal conditions but it was thought that for this study, counterbalancing was methodologically sounder. Full details are given of procedures used, page 140

The task was included since it defines a pattern detection problem, in which extraction of the rule for solving the problem (correct discrimination) is thought to be achieved by active reduction of errors, including response to reinforcement. This is thought to be a function of internal inhibition. The task was a means of eliciting the strategies used by children in search for the pattern, and test results were expected to show a decline in perseverative and alternating strategies over age correspondingly, an increase in flexible strategies used in response to cues and errors would be observed.

Three-Choice Visual Discrimination Learning

As reviewed in Chapter 1, this task was used by Weir (1964) in a study of developmental changes in children's problem-solving abilities using two alternative conditions of reinforcement. The Three-Choice Discrimination Learning Task would seem to be a useful test of the ability to utilise cues and errors in pattern detection, and for use as a comparison with the utilisation of strategies on tasks of varying complexity. Further, the task appeared to tap the ability to inhibit incorrect responses following non-reinforcement.

The apparatus and randomised delivery of reinforcement used by Weir (1964) could not be duplicated because of the contingent nature of reinforcement to correct response. The apparatus and random schedule of reinforcement are nevertheless considered to be equivalent, although in discussion of Weir's results in comparison to those obtained from the present study, it will be suggested that Weir's apparatus itself gave a misleading cue as well as the important features of the instructions used. In this study, the modified Wisconsin General Testing Apparatus used in Two-Choice Discrimination Learning has been employed, and is described in the Procedure section.

The Attributes Task

The literature relevant to the use of this task is reviewed in Chapter 1, pages 38 and 39 for the purpose of this research, the version of the Attributes task used by Spiker and Cantor (1979) was thought preferable to that used by Gholson, Levine and Phillips (1972). In the latter task there were difficulties of interpretation, and these are reviewed in Chapter 1. However, letter shapes were used by Gholson, Levine and Phillips and this feature was incorporated into the present task. The colour and shape attributes used by Spiker and Cantor were considered too close to those to be used in Wisconsin Card Sorting Test. The attributes to be used in this study were the letters T, V, X, and O. No blank trials procedure is included.

Experimental Design

The administration of a battery of tasks to subjects on any test occasion necessitates randomisation to avoid the risk of order effects confounding the results. In this research, not only were 6 experimental tasks administered to each child, but the process was repeated on each of the 4 occasions during a 2 year period at 7-8 month intervals. These four intervals were chosen to allow for developmental changes to be observed. It was considered that the intervals are of sufficient length for immediate practice effects to be dissipated. Re-testing would thus yield evidence of behavioural change from developmental advance, and yet allow retention of contact with the children. The risk was accepted of experimental mortality, a hazard of longitudinal research and which is considered on page 77 , Chapter 1. Where this occurred early in the research, fresh children were substituted. Five such substitutions took place, all from the LSES group.

Randomisation of order of task presentation was thus carried out for each child and for each test occasion. A safe-guard of avoidance of fatigue for children, and the resulting risk of bias was referred to on page 127
The total testing time needed for the administration of the 6 task battery on each occasion was 45 minutes, and this was divided into 2 test sessions on consecutive days for each subject, but at different times of the day, again for the purpose of randomisation of sources of error. A further test session was required before the first testing occasion for administration of the Pre-tests. Full details of the repeated measures experimental design, and task order, including conditions assigned for each subject and testing, are given in Appendices 2 and 3.

The Sample

A sample of 96 children was drawn from schools and playgroups, equally by sex and socio-economic status according to the Registrar General's classification of occupations (1970). Of the total sample, 48 children attended schools or playgroups in two inner London boroughs, and constituted the lower socio-economic half of the sample. The other 48 children attended schools or playgoups in a commuter suburb of Essex, serving a predominantly upper socio-economic population. The procedure was considered to ensure a representative sample of children from different social backgrounds. It was, however, accepted that social experience defines a continuous, rather than a dichotomous variable although it is related to socio-economic group membership (Wells 1979). This is discussed further in Chapter 5.

The total sample of 96 was divided into 3 age levels of mean ages 3.4 years (N=32, range 3.0-3.8) 5.2 years (N=32, range 5.0-5.5) and 7.2 years (N=32, range 7.0-7.8). Each of the 3 age levels at the start of the study thus contained equal numbers of boys and girls, and of the socio-economic groupings. A total of 11 schools and 3 playgroups provided the source of subjects, and in each case the permission of the headteacher, the local education authority, and the parents was obtained. Appendix 6 contains a full list of schools used in both pilot study, and main study. All subjects were selected as being without known handicap, and as possessing English as a mother tongue. In the early stages of the research, three subjects were discarded, following pre-tests which indicated particularly low ability on RCPM or the Language Comprehension sub-scale, and in one case, a child with mild spina bifida with known general learning difficulties. The curriculum of the schools was considered to be substantially similar in organisation and approaches to the basic skills, and similarly, the playgroups showed a common form of organisation. No child used in the pilot study has been included in the main study, nor have schools or playgroups.

Since the field work for the study was begun in 1980, when the pre-school and younger Primary school age population was at a low point, the meeting of the criteria for selection meant that, in practice, all children in the relevant age groups in the schools and playgroups were included. There was, thus, no necessity to select at random from the target age ranges. During the two year period of testing, many of the children transferred school, i.e. from infant to separate junior school, and all playgroup children entered school. The remaining testings for all such children took place in the school being attended, and where necessary, after allowing for adjustment. The teachers' judgments were sought in this respect.

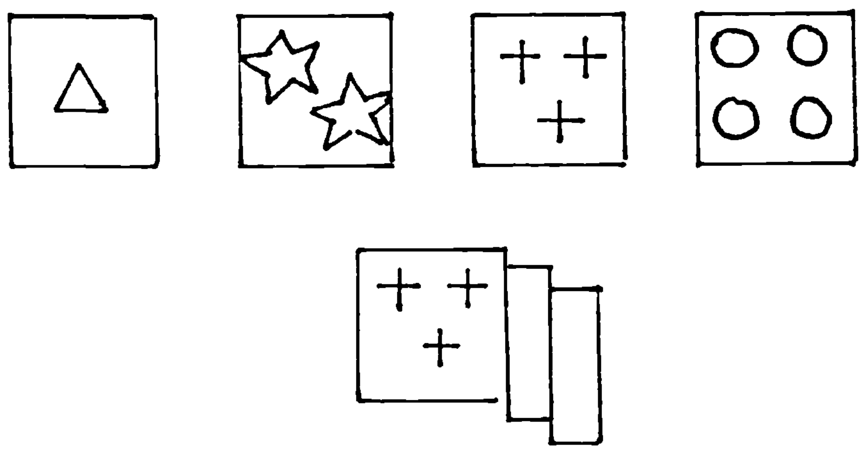
Procedure

Prior to the administration of the experimental task battery on the first test occasion and similar to practice in the pilot study (Appendix 1), the experimenter spent time in each classroom to help children feel at ease in the coming test session. In the case of the 3 year old sub-sample, the experimenter joined in the playgroup activities, with particular attention to the play of the target children, who might be expected to be less than co-operative with a relative stranger. In the event, only 2 children could not be persuaded to 'play the games' after pre-tests. These were both boys, one from each of the socio-economic groups. Fresh subjects were substituted. Five further substitutions were made for children (three 3 year olds, two 5 year olds) whose attendance at school was spasmodic. Appendix 4 contains samples of completed scoring sheets for all experimental tasks used.

Administration Procedures for the Experimental Task Battery - Wisconsin Card Sorting Test

Materials - shown as presented to the subject

Figure 3



The child is shown the test material as pictured in the diagram.

4 stimulus cards are shown, differing in colour, form and number: 1 red triangle, 2 green stars, 3 yellow crosses, and 4 blue circles.

A pack of 64 response cards which vary along the same dimensions of colour, form and number.(Milner 1964), with instructions.

Instructions

'Here is a pack of cards. I want you to put each card next to the one you think it goes with. I will tell you if you are right or wrong. Try to get as many as you can right'. Cards handed to the child one at a time. Except for the cue 'right' or 'wrong' to each card placement, no other cues were given. Milner's (1964) procedure was followed, except for the reduction in card pack size, and which was referred to in the description of the task on page of this chapter. Sorting was first to colour, and all other responses were designated wrong.

After 10 consecutive correct responses to colour, the required sorting principle shifted to form, without prior warning, and colour now became wrong. Again, after 10 consecutive correct respon es to form, the principle shifted to number, then back to colour again.

The procedure continued until the child had successfully completed 6 sorting categories (colour, form, number, colour, form, number) or until all 64 cards had been placed.

Scoring

Each response was recorded to enable analysis of

a) type of response - e.g. perseverative/alternating

b) number of responses to criterion of 10 correct responses for each category

c) number of sorting categories established - maximum 6

d) correct/incorrect.

Spontaneous Alternation

Materials

A pack of 30 cards, each 4 cm square, containing 15 cards, red on one side, and 15, blue on one side. The reverse side of each card was white.

The cards were shuffled in front of the child and a check was made that colours were correctly named.

Instructions

'Can you see the cards are all mixed up now?' (indicating mix) 'I want you to guess what colour each card is'
The cards were then placed face down on the table one at a time, and the child was reminded 'Guess what colour this card is'. At the end of testing, the cards were turned

face up, and the child was informed that he/she had done well. A prompt was given if the child named colours not contained in the pack - a phenomenon sometimes found with the youngest children.

Scoring

Recording of colour guesses on a prepared sheet to permit analysis of choices.

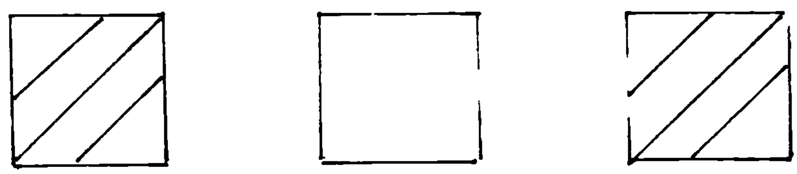
Oddity Problem

Materials

Set of coloured 4 cm cards, two of each of green, light blue, red, orange, green, yellow, purple, black, dark blue, ochre.

Figure 4

e.g.



For each problem a fresh selection was made of two identically coloured cards and one odd one. The position of the odd one was counterbalanced across trials,(Appendix 4-scoring sheet.) A marble was given for each correct choice, and cashed at the end for some Smarties. There were two criteria for solution 1) not more than 3 errors in 18 successive trials

2) errorless solutions on 5 x 1 trial problems.

Instructions

'I want you to choose a card' - point to cards
'If you choose the right one, I will give you a marble.
Try to be right every time' Cards are withdrawn after each trial, and re-presented on each new trial.
No other instruction was given, except that for every failure after trial 30, a hint was provided 'there is a trick to get it every time' (this hint was used by Lunzer 1968).
A maximum of 60 trials was given.

2nd stage 'How did you know which one to choose?'

3rd stage 'Could you make some puzzles for me to do that are just like the one's you have done?
S was then required to set an oddity problem for the experimenter to solve.

Scoring - on prepared sheet - to show:

a) child's response showing whether correct/incorrect

b) position of choice to allow analysis of whether responses

c) whether oddity problem solved, and at what stage of trials (discrimination)

d) whether generalisation is made

e) ability to give a verbal justification of the solution part of oddity

f) whether child could set experimenter an oddity problem

2 Choice Visual Discrimination Learning

Two conditions were given in counterbalanced order

a) first choice correct - no reversal required;

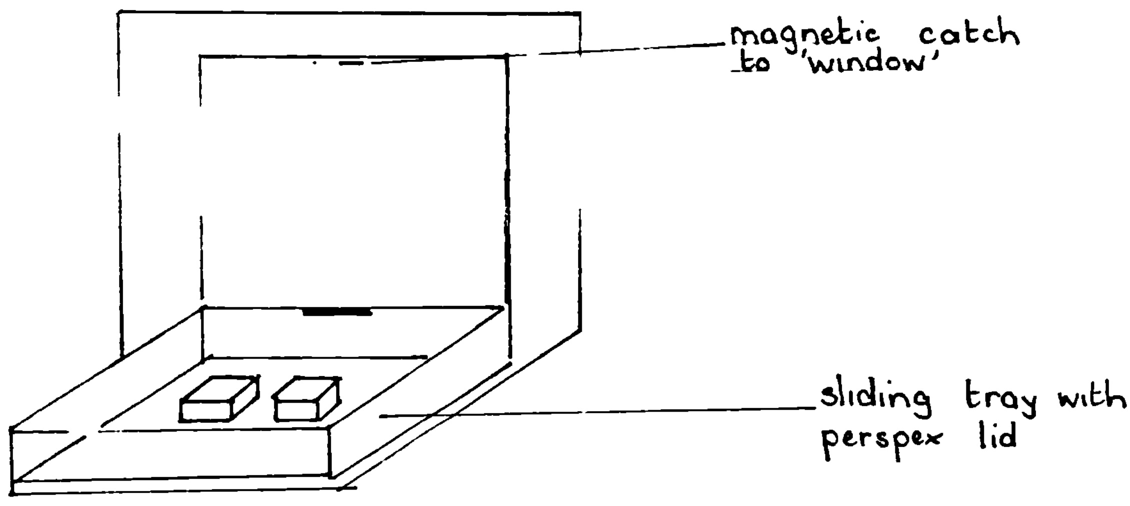
b) first choice incorrect - reversal required.

Each child experienced both orders of presentation on each testing occasion on a pre-determi ed schedule. Half the children at each age level therefore experienced the order as abab, and the other half as baba during the four testing occasions.

Materials

Two 4 cm wooden boxes, with grooved base to hold marble and with hinged lid presented on sliding tray of modified Wisconsin General Testing Apparatus. This had a hardboard screen to shield the boxes, whilst one was being loaded with a marble. Each box was topped by a coloured card.

Figure 5 - Modified Wisconsin General Testing Apparatus



Instructions

'Here are 2 boxes. One of them will have a marble in every time. Try to choose the box with the marble in. Try to be right every time.'

The screen was lowered while the box was loaded. On condition a) both boxes contained a marble on the first trial to ensure that first choice was always correct. On subsequent trials, the first chosen box became the rewarded box. In condition b) neither box contained a marble on first trial, and the chosen box became the incorrect box. After the first choice, 20 further trials were given on each condition.

Scoring

The child's responses were recorded on a prepared sheet to allow analysis of number of errors on each condition and strategies used.

Three Choice Visual Discrimination Learning

Weir's procedure reported in 1964 study was followed and for each subject one of the three cubes, right, middle or left, was previously designated correct. For each testing, the correct position of left, middle or right was altered. All children therefore experienced all three positions in a randomised order. In each of the two conditions, the correct cube yielded either 33% or 66% reinforcement, and a pre-arranged random schedule was used to determine which trials were to be reinforced if the correct cube was chosen.

Forty-eight children were allocated to each of the two reinforcement conditions, and were drawn equally by sex and socio-economic status from each of the age groups, 3, 5 and 7 years.

Materials

The modified Wisconsin General Testing Apparatus was used as for Two-Choice Discrimination Learning (Figure 5), with the addition of a grey cardboard base inside the sliding tray. Three green Unifix cubes, used in schools for mathematics work, were placed in the base at equidistant intervals. A tray placed near the child served as the receptacle, into which marbles as reinforcers were placed, and the child was told 'Here's a tray for marbles. If you win some marbles I-shall put them in here'. The apparatus was considered analogous to that used by Weir, although it did not use the signal light which possibly directs subject's attention to the centre position, and thus provides a misleading cue. This aspect is considered fully in Chapter 5.

Instructions

Children were told 'Every time I lift the window, I want you to choose a cube. The game is to win as many marbles as you can'. The signal to begin a trial by lifting the window, was considered analogous to that given for subjects in the experiments reported by Weir (1964 who were told

'When the light comes on, you push one of the knobs'. Issues raised by Weir's form of instruction in relation to his results are discussed in Chapter 5.

Eighty trials were given, in accordance with Weir's procedure. On completion, Smarties or Jellytots to choice were given, irrespective of whether, or how many, marbles had been won. This procedure was considered analogous to that used by Weir.

Scoring

A prepared recording sheet enabled full details of each child's positive responses to be noted, to allow analysis of error number and type.

The Attributes Task

Materials

Four square white cards 6.5 cm square, each printed with a form outlined in heavy black ink from T V X O which are 2.5 cm in height.

Instructions

These are placed in front of the child in the order T V X O The child was told 'Here are 4 shapes' (experimenter pointed to each in turn). 'One of the shapes is special and gets a marble every time. I want you to try to find which is the special shape. Try to be right every time'. The phrase 'special shape' was used by Spiker and Cantor (1979). On the first trial, none of the forms were rewarded, and this procedure was used to ensure that a reversal must be made to achieve criterion. Prior to the second trial, the experimenter designated one of the forms not chosen as the correct one, with the further proviso that a position shift was required. The forms were presented in the order T V X O, X O T V, X V T O throughout the 40 trials of the task.

Scoring

A prepared form enabled an exact recording of choices made by each child. A marble was given for each correct choice, and at the end of the test, sweets were given in place of the marbles. The criterion of success is 8 consecutive correct choices, and for those who did not achieve criterion, testing terminated after 40 trials.

CHAPTER 4

RESULTS

The results chapter is organised in line with the previous chapter, with results given in a similar order to that of the null-hypotheses, as stated.

Initially, Factor Analysis results are given, followed by the four-way analysis of variance, after intervening tests for practice effects, attributable to the use of a repeated measures design. Subsequently, within task differences are analysed by a variety of techniques, e.g. t test, binomial test, analysis of variance. Correlations between pre-tests and experimental tasks are presented as matrices. Finally, within-child changes are examined by curve-fitting.

The full raw data is given in micro-fiche form in Appendix 8. Samples of completed scoring sheets are included in Appendix 4.

FACTOR ANALYSIS

Principal Components Factor Analysis was carried out using the SPSS Factor Programme as a preliminary test for age-related differences in perseveration scores obtained on each of the experimental tasks. This is done separately for each of the four test occasions. This analysis enabled the extraction of age and other factors common to perseveration scores obtained on each task. The hypotheses under test are stated in the null form for each experimental task, and are listed on pages 116,117, Chapter 2, as 1, 3, 5, 7, 9, 11. Additionally, hypotheses relating to correlations between age and tasks are given as 13 and 14.

Variables entered into each Principal Component Factor Analysis were:

1. Age in months (Age)
2. Perseveration error scores on the Wisconsin Card Sorting Test (WCST)
3. Perseveration scores on the Spontaneous Alternation Task (Sp.Alt)
4. Perseveration error scores on the Oddity Problem (Oddity)
5. Perseveration error scores on the Two-Choice Discrimination Learning Task (2 choice Discrim.)
6. Perseveration error scores on the Three-Choice Discrimination Learning Task (3 choice Discrim.)
7. Perseveration error scores on the Attributes Task

The matrix of correlation co-efficients between variables, Principal Components and Varimax Rotation of these are stated separately for each testing. For these, abbreviated variable names are used, as shown in brackets above.
As stated in Chapter 2, page 118, a significance level of .05 is accepted as sufficient to reject a null hypothesis. For the sample size of 96, $p < .05$, $r \geq 0.20$.

Table 3

Matrix of correlation co-efficients between age and tasks - Testing 1 - all subjects (N=96)

	Age	WCST	Sp.Alt	Oddity	2 choice Discrim.	3 choice Discrim.	Attributes
Age		-47	-55	-41	-21	-54	-27
WCST			30	21	16	23	08
St.Alt				33	35	62	37
Oddity					26	37	33
2 choice Discrim.						35	29
3 choice Discrim.							42

Table 4

Factor Matrix - Testing 1

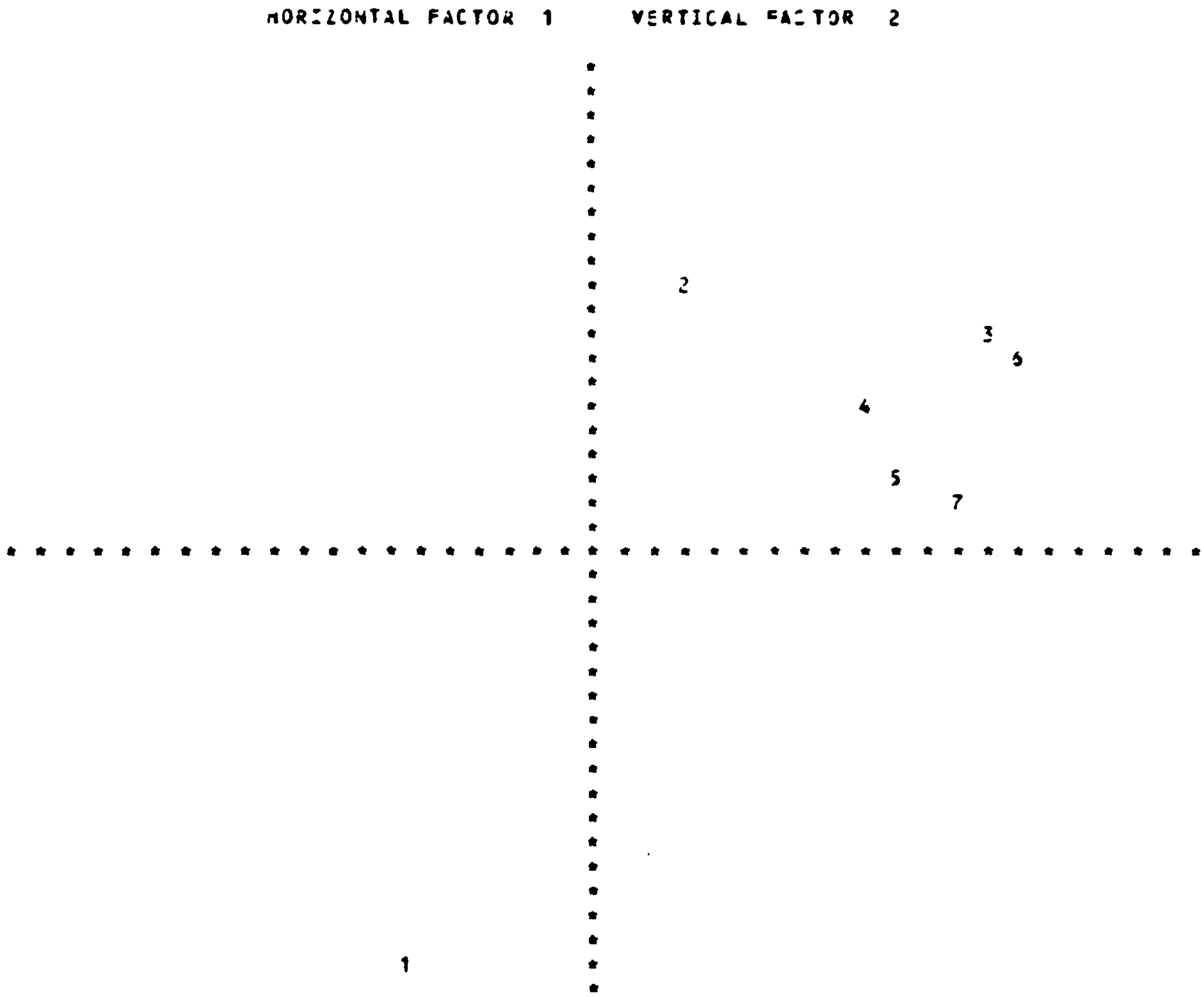
FACTOR MATRIX USING PRINCIPAL FACTOR WITH ITERATIONS

	Factor 1	Factor 2	Communality
Age	-0.80	0.42	0.81
WCST	0.42	-0.32	0.28
Sp.Alt	0.74	0.06	0.55
Oddity	0.52	0.05	0.27
2 choice Discrim.	0.43	0.22	0.24
3 choice Discrim.	0.76	0.16	0.60
Attributes	0.50	0.32	0.35

FACTOR	EIGENVALUE	PCT OF VAR
1	2.66	84.9
2	0.47	15.1

Varimax (orthogonal) rotation was carried out for each testing. This procedure helps clarify test loadings for purposes of interpretation of the Factor Analysis. The resulting diagrams are presented as Figures 6 to 9

Figure 6 Varimax rotation - Factors at Testing 1



It may be noted that of the two factors extracted, Factor I accounted for 84.9 per cent of variance, and obtained an Eigenvalue of 2.66. Since little variance (15.1%) remained for Factor 2, which obtained a Eigenvalue of less than 1 (.47), in accordance with Child (1970), the second factor is disregarded.

Table 5

Matrix of correlation co-efficients between age and tasks -

Testing 2 - All subjects (N=96)

	Age	WCST	Sp.Alt	Oddity	2 choice Discrim.	3 choice Discrim.	Attributes
Age		-58	-30	-49	-23	-55	-36
WCST			28	41	01	33	22
Sp.Alt				37	26	52	50
Oddity					13	59	43
2 choice Discrim.						28	21
3 choice Discrim.							60

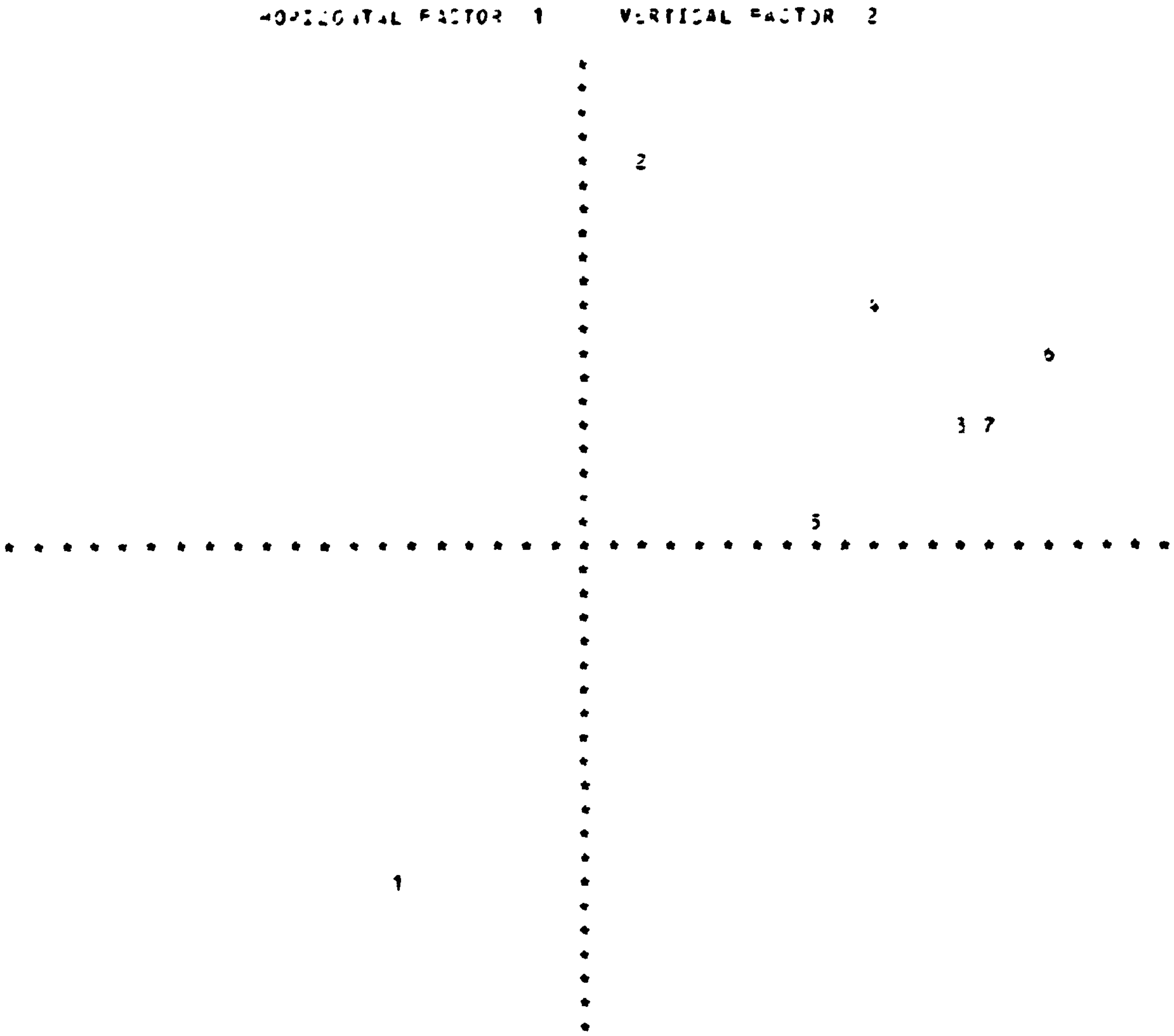
Table 6 FACTOR MATRIX - TESTING 2

FACTOR MATRIX USING PRINCIPAL FACTOR WITH ITERATIONS

	Factor 1	Factor 2	Communality
Age	-0.71	0.30	0.60
WCST	0.57	-0.55	0.64
Sp.Alt	0.60	0.22	0.41
Oddity	0.67	-0.04	0.46
2 choice Discrim.	0.29	0.20	0.12
3 choice Discrim.	0.84	0.21	0.75
Attributes	0.65	0.29	0.52

FACTOR	EIGENVALUE	PCT OF VAR
1	2.89	82.2
2	0.62	17.8

Figure 7 Varimax rotation - Factors at Testing 2



At the second testing Factor 1 accounted for 82.2 per cent of Variance, with Eigenvalue of 2.89. Factor 2 is considered non significant (Eigenvalue .62), and is not discussed further.

Table 7

Matrix of correlation co-efficients between age and tasks -

Testing 3 all subjects (N=96)

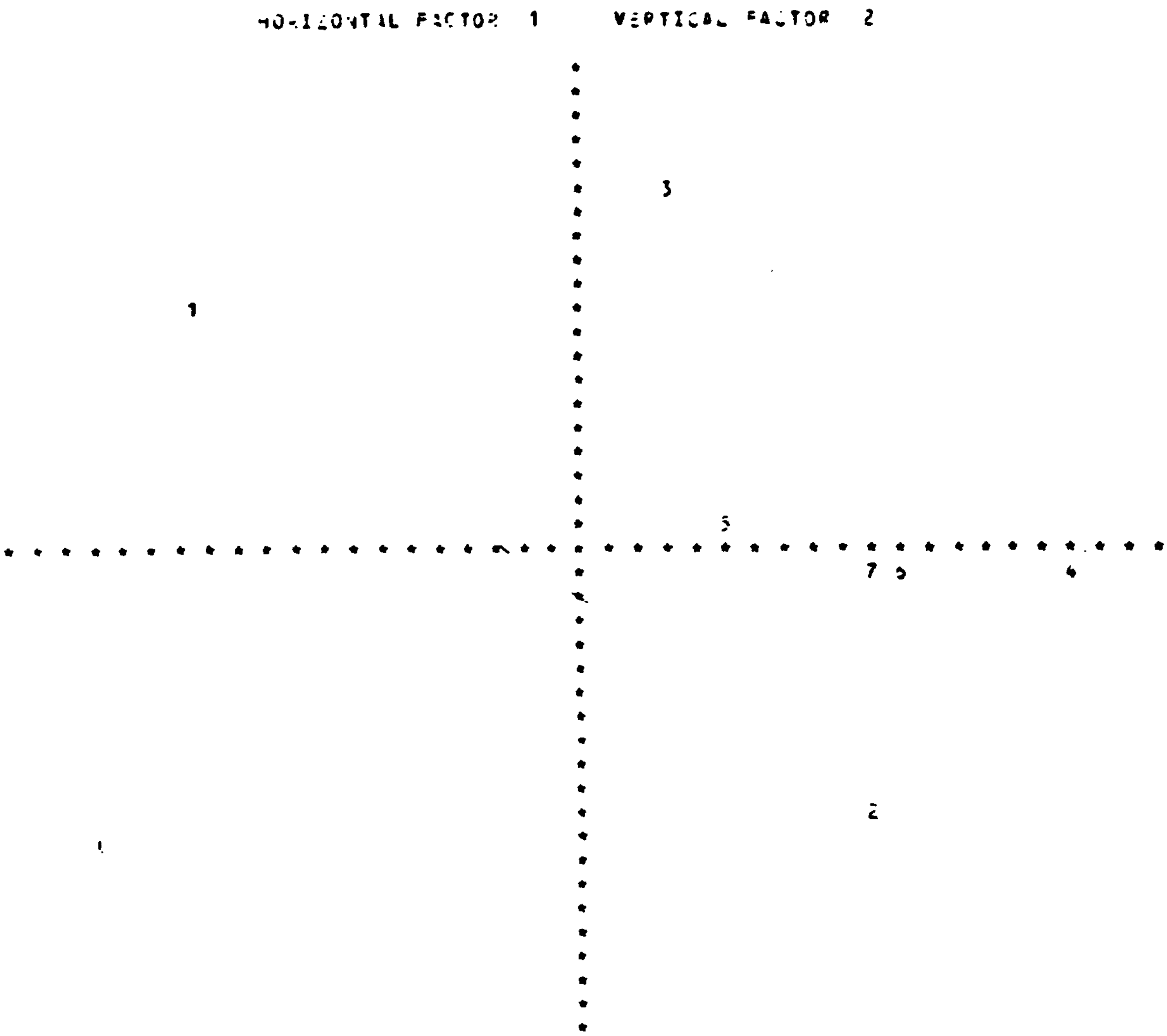
	Age	WCST	Sp.Alt	Oddity	2 choice Discrim.	3 choice Discrim.	Attributes
Age		-55	24	-55	-23	-32	-35
WCST			-29	40	08	33	19
Sp.Alt				09	07	06	01.
Oddity					14	45	42
2 choice Discrim.						07	08
3 choice Discrim.							29

Table 8 PRINCIPAL FACTOR MATRIX - TESTING 3

	Factor 1	Factor 2	Communality
Age	-0.78	0.16	0.65
WCST	0.63	-0.28	0.48
Sp.Alt	-0.15	0.70	0.52
Oddity	0.77	0.30	0.69
2 choice Discrim.	0.19	0.08	0.04
3 choice Discrim.	0.51	0.18	0.29
Attributes	0.46	0.16	0.24

FACTOR	EIGENVALUE	PCT OF VAR
1	2.16	73.7
2	0.77	26.3

Figure 8   Varimax rotation Factors at Testing 3



Again two factors were extracted, with Factor 1 accounting for the major part of the variance (73.7) and with Eigenvalue of 2.16. Factor 2, consistent with the second factor extracted in Testings 1 and 2, obtained an Eigenvalue of less than 1 (.77) which is not considered significant, although it should be noted that 26.3 per cent of variance is accounted for.

Table 9

Matrix of correlation co-efficients between age and tasks -

- Testing 4 all subjects (N=96)

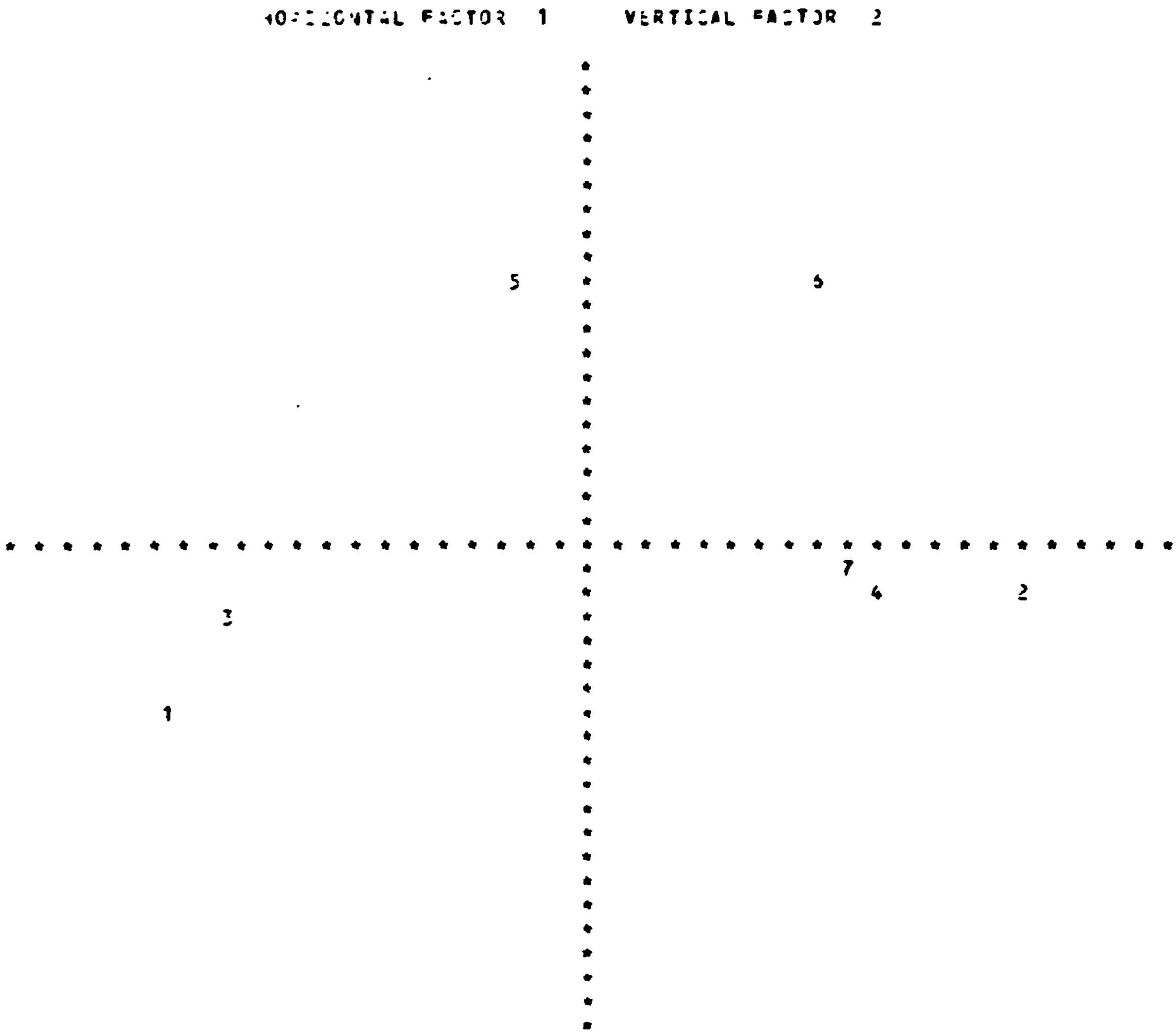
	Age	WCST	Sp.Alt	Oddity	2 choice Discrim.	3 choice Discrim.	Attributes
Age		-52	50	-36	-09	-45	-23
WCST			-45	25	-13	22	36
Sp.Alt				-29	01	-32	23
Oddity					-11	08	22
2 choice Discrim.						21	-06
3 choice Discrim.							23

Table 10 PRINCIPAL FACTOR MATRIX - TESTING 4

	Factor 1	Factor 2	Communality
Age	-0.79	-0.13	0.64
WCST	0.68	-0.24	0.52
Sp.Alt	-0.64	0.02	0.41
Oddity	0.41	-0.20	0.21
2 choice Discrim.	0.00	0.55	0.31
3 choice Discrim.	0.50	0.39	0.41
Attributes	0.41	-0.11	0.18

FACTOR	EIGENVALUE	PCT OF VAR
1	2.11	77.8
2	0.60	22.2

Figure 9 Varimax rotation Factors at Testing 4



Two factors were extracted for this final testing, with Factor 1 accounting for 77.8 per cent of variance and yielding an Eigenvalue of 2.11. The second Factor, although accounting for the remaining 22.2 per cent of variance, has an Eigenvalue below 1 (.60) and is therefore not considered significant.

From Figure 9, it can be seen that age is no longer placed alone, but that Spontaneous Alternation would additionally appear to be contributing substantially to Factor 1. The possible significance of this, and location of variables is considered in Chapter 5, together with implications from comparison with Factor Analyses for Testings 1, 2 and 3.

Child (1970) suggested that factor analysis is a useful 'device for ordering and simplifying correlations between related variables'. It has limitations, which include its correlative nature, and appears to be most appropriate when linearity of relationships can be assumed and where homogeneity of the sample obtains, as in this study. In the case of data for the present study, linear relationships between age and individual variables appear to be the case, with the exception of that for Spontaneous Alternation where a curvilinear relationship best describes the data. Nevertheless, as a preliminary set of analyses, particularly Factor Analysis of Testing 4, designed to take age into account. Mean and standard deviations of perseverations on each of the variables, at each age level, and from each testing are presented as Tables 12, 13, 14, 15, 16, 17, together with means and standard deviations of pre-test scores (Table 11).

Table11 Means and Standard Deviations for Pre-Tests

		3 yrs	5 yrs	7 yrs
Ravens Coloured Progressive	$\bar{x}$	8.22	14.31	18.88
Matrices - Raw scores	s.d	2.41	3.50	4.47
Reynell Language Comprehension	$\bar{x}$	-0.02	0.21	-0.46
Sub-scale - Standard Scores	s.d	0.90	0.76	1.08
Matching Familiar Figure	$\bar{x}$	4.26	7.55	9.60
Latency time in seconds	s.d	1.88	4.55	3.62
Matching Familiar Figures	$\bar{x}$	1.72	3.09	4.19
No. of 1st time correct responses	s.d	1.17	1.47	2.09

MEANS AND STANDARD DEVIATIONS BY AGE, TASK AND TESTING

Table 12 Mean Perseveration errors Wisconsin Card Sorting Test

Age at start	Testing 1		Testing 2		Testing 3		Testing 4	
	$\bar{x}$	s.d	$\bar{x}$	s.d	$\bar{x}$	s.d	$\bar{x}$	s.d
3 years N=32	22.59	9.41	21.90	8.64	18.68	7.15	17.28	8.35
5 years N=32	17.18	8.55	14.03	6.58	12.84	5.16	10.37	3.92
7 years N=32	12.65	4.67	9.60	4.50	9.87	3.73	8.04	3.39
Total sample N=96	17.47	8.75	15.20	8.42	13.80	6.59	12.02	6.79

Table 13 Mean Perseveration - Spontaneous Alternation

Age at start	Testing 1		Testing 2		Testing 3		Testing 4	
	$\bar{x}$	s.d	$\bar{x}$	s.d	$\bar{x}$	s.d	$\bar{x}$	s.d
3 year N=32	21.34	8.52	13.06	10.18	5.00	5.68	2.90	3.95
5 year N=32	7.28	6.18	5.59	6.76	5.65	4.65	7.15	4.62
7 year N=32	8.62	4.77	6.93	4.85	7.84	3.93	8.81	3.75
Total sample N=96	12.41	9.17	8.53	8.19	6.16	4.91	6.29	4.79

Table 14 Mean Perseveration errors - Oddity Problem

Age at start	Testing 1		Testing 2		Testing 3		Testing 4	
	$\bar{x}$	s.d	$\bar{x}$	s.d	$\bar{x}$	s.d	$\bar{x}$	s.d
3 years N=32	10.68	10.18	10.96	11.35	4.28	3.76	1.96	2.64
5 years N=32	1.85	2.43	1.50	2.10	0.37	0.55	0.28	0.52
7 years N=32	2.03	6.99	1.03	2.55	0.28	0.52	0.34	0.70
Total sample N=96	4.86	8.30	4.50	8.17	1.64	2.88	0.86	1.77

Table 15 Mean Perseveration errors - 2 Choice Discrimination Learning

Age at start	Testing 1 $\bar{x}$	Testing 1 s.d	Testing 2 $\bar{x}$	Testing 2 s.d	Testing 3 $\bar{x}$	Testing 3 s.d	Testing 4 $\bar{x}$	Testing 4 s.d
3 years N=32	3.03	6.65	0.93	1.34	0.62	0.60	0.34	0.54
5 years N=32	0.46	0.50	0.46	0.76	0.34	0.48	0.37	0.49
7 years N-32	0.81	0.96	0.37	0.49	0.31	0.59	0.25	0.43
Total sample N=96	1.43	4.02	0.59	0.95	0.42	0.57	0.32	0.49

Table 16 Mean Perseveration errors - 3 Choice Discrimination Learning - Both Conditions Combined

Age at start	Testing 1 $\bar{x}$	Testing 1 s.d	Testing 2 $\bar{x}$	Testing 2 s.d	Testing 3 $\bar{x}$	Testing 3 s.d	Testing 4 $\bar{x}$	Testing 4 s.d
3 years N=32	33.59	23.48	27.65	21.50	9.68	14.72	6.21	5.64
5 years N-32	10.00	13.03	2.96	3.02	3.84	6.74	2.75	3.81
7 years N=32	5.21	12.78	3.56	6.11	1.87	2.13	1.28	1.61
Total sample N=96	16.27	21.07	11.39	17.31	5.13	9.90	3.41	4.50

Table 17 Mean Perseveration errors - Attributes

Age at start	Testing 1 $\bar{x}$	Testing 1 s.d	Testing 2 $\bar{x}$	Testing 2 s.d	Testing 3 $\bar{x}$	Testing 3 s.d	Testing 4 $\bar{x}$	Testing 4 s.d
3 years N=32	17.03	9.53	12.90	8.06	8.78	6.54	4.09	5.00
5 years N=32	8.00	8.91	1.81	2.41	3.31	9.08	2.15	3.41
7 years N=32	9.71	13.47	5.81	7.73	2.56	3.14	1.84	1.95
Total sample N=96	11.58	11.41	6.84	7.99	4.88	7.20	2.69	3.77

Practice effects in a Repeated Measures Design

The Principal Components Factor Analyses, which have been carried out for each testing separately as a preliminary, indicated that age is the principal common factor in perseveration scores. Results of these, together with visual inspection of means for each of the experimental task variables, at each age level, pooled for sex and social class, and for each testing, suggest that the null hypotheses (1, 3, 5, 7, 9, 11) (there would be no age-related differences in perseverations on each task), do not receive support.

Before proceeding to further analysis for main effects between age, sex and social class, and significance testing of age-related changes within children over the four test occasions, a series of t-tests for independent samples were carried out to test for practice effects. These may arise as a result of repeated measures, and thus of familiarity with the test material. It was thus decided to test for significance between means of each set of test scores of the 3 year old group at Testing 4 and 5 year olds at Testing 1, and between 5 year olds at Testing 4 and 7 year olds at Testing 1. The experimental design had been so constructed to allow for cross-sectional comparison between overlapping samples, as well as for longitudinal analysis. Results of cross-sectional comparison are reported as Tables 18 and 19.

Table 18 Results of t-tests (independent samples) on perseveration scores from experimental tasks 3 years and 5 years

Task name	Mean 3 yrs. Testing 4	Mean 5 yrs. Testing 1	t value	Sig level
Wisconsin Card Sorting Test	17.28	17.19	.04	
Spontaneous Alternation	2.91	7.28	3.37	.05
Oddity Problem	1.97	4.34	1.67	
2 Choice Discrimination Learning	.34	.47	.95	
3 Choice Discrimination Learning	5.91	10.00	1.64	
Attributes	4.09	8.00	2.16	.05

Table 19 Results of t-tests (independent samples) on perseveration scores from experimental tasks 5 years and 7 years

Task name	Mean 5 yrs. Testing 4	Mean 7 yrs. Testing 1	t value	Sig level
Wisconsin Card Sorting Test	10.38	12.66	2.11	.05
Spontaneous Alternation	7.16	8.31	.97	
Oddity Problem	.28	2.03	1.41	
2 Choice Discrimination Learning	.38	.81	2.28	.05
3 Choice Discrimination Learning	2.75	5.22	1.05	
Attributes	2.16	9.72	3.08	.05

It can be seen from tables 18 and 19 that some differences in means are statistically significant, suggesting that performance has been influenced by practice, particularly at the end of the seventh year. Implications of this are discussed in Chapter 5, and in particular, the possibility that practice effects are themselves a function of age.

(For each t test, df equal 62)

Four-Way Analysis of Variance

The preceding pages reported some significant differences between means on the experimental task battery, which may be attributed to practice effects from repeated measures. However, the t-tests carried out, . and reported in tables 18 and 19 were derived from a sub-sample of data, and from a cross-sectional design. Further, as already discussed, the preliminary Principal Components Factor Analyses carried out on data gained from experimental task variables for all subjects indicated that age is the common factor in perseveration scores. There is thus a lack of support for the null hypotheses (1, 3, 5, 7, 9, 11) that there would be no significant age-related differences in scores in each task. However, before rejecting these null hypotheses, and in order to test the further null hypotheses (2, 4, 6, 8, 10, 12) that there would be no significant differences within children on each of the six experimental tasks, a series of Four-Way Analysis of Variance was carred out. Perseveration errors for all tasks, except Spontaneous Alternation (perseverations only) were used to obtain scores from each of the four testings and used as the dependent variables.

Three grouping factors, age, sex and social class, were used to obtain main effects from independent variables, and also to yield interactions of these. A repeated measures design was selected, since data from dependent variables was derived from an initial test and three subsequent re-tests. The experimental design (Chapter 3 and Appendix 3) had taken possible task order effects into account by counterbalancing this across subjects and testings, and thus no further control in analysis was considered necessary. The BMDP 2V programme was selected for analysis by computer, since it best satisfied the criteria of a mixed model design (Jennrich, Sampson and Frane in BMDP Statistical Software 1981). Results from each separate ANOVA are presented in Tables 20, 22, 25, 28, 31, 34, 37 and for Trends deriving from these as Tables 21, 23, 24, 26, 27, 29, 30, 32, 33, 35 36, 38, 39 and figures 10, 11, 12, 13, 14, 15, 16, 17, 18. A significance level of .05 for tests of interaction effects is considered, as stated on page 118 Chapter 2, sufficient to reject a null hypothesis. Additionally, the .05 level of significance applies to test of null hypotheses relating to main effects of sex and social class differences.

Table 20 Four-Way Analysis of Variance - Wisconsin Card Sorting Test

Source	Sum of Squares	df	Mean Square	Fratio	Sig. level
Between					
Age	6549.16	2	3274.58	57.49	.001
Sex	153.77	1	153.77	2.70	
SES	223.56	1	223.56	3.92	.05
Age x Sex	175.42	2	87.71	1.54	
Age x SES	67.25	2	33.62	.59	
Sex x SES	265.00	1	265.00	4.65	.05
Age x Sex x SES	270.22	2	135.11	2.37	
Error	4784.59	84	56.95		
Within					
Testings	1530.75	3	510.25	14.87	.0 1
Testings x Age	167.17	6	27.86	.81	
Testings x Sex	50.36	3	16.78	.49	
Testings x SES	135.27	3	45.09	1.31	
Testings x Age x Sex	365.91	6	60.98	1.78	
Testings x Age x SES	171.74	6	28.62	.83	
Testings x Sex x SES	70.54	3	23.51	.69	
Testings x Age x Sex x SES	447.19	6.	74.53	2.17	.05
Error	8647.78	252	34.31		

The table shows a significant four-way interaction effect between Testings, Age, Sex and SES. Means are thereforegiven in a tree form diagram as Figure 10, and which is considered to be the most meaningful form for interpretation of a four-way interaction. Trend Analysis of Testings is then given as Table 21.

Fig 10 Four-Way Interaction - Testings x Age x Sex x SES
Wisconsin Card Sorting Test

AGE	Sex	SES	Testing 1	Testing 2	Testing 3	Testing 4
3 Years	Boys	USES	22.13	22.00	16.38	16.00
		LSES	16.25	19.63	15.88	20.00
	Girls	USES	24.38	17.38	18.63	14.00
		LSES	27.63	28.63	23.88	19.13
5 years	Boys	USES	18.13	10.38	15.13	10.13
		LSES	16.5	16.63	12.38	7.88
	Girls	USES	13.75	14.63	9.63	10.75
		LSES	20.38	14.5	14.25	12.75
7 years	Boys	USES	13.63	7.38	8.5	9.00
		LSES	11.38	10.88	11.5	8.25
	Girls	USES	13.88	10.63	9.75	6.63
		LSES	11.75	9.88	9.75	9.75

Table 21 Analysis for Trend - Testings
Wisconsin Card Sorting Test.

Source	S.S	df	M.S	F.ratio	Sig. Level
Within Treatments	1530.75				
Linear Trends	1517.62	1	1517.62	40.03	.001
Non linear Trend					
Quadratic	5.75	1	5.75	.21	
Cubic	7.37	1	7.37	.20	

Table 22 Four-Way Analysis of Variance - Spontaneous Alternation

Source	Sum of Squares	df	Mean Square	Fratio	Sig. level
Between					
Age	1122.48	2	561.24	9.64	.001
Sex	317.19	1	317.19	5.45	.05
SES	11.00	1	11.00	0.19	
Age x Sex	159.16	2	79.58	1.37	
Age x SES	0.38	2	.19	0.00	
Sex x SES	87.21	1	87.21	1.5	
Age x Sex x SES	0.57	2	0.28	0.00	
Error	4891.78	84	58.23		
Within					
Testings	2455.13	3	818.37	29.9	.0 1
Testings x Age	4482.01	6	747.00	27.3	.001
Testings x Sex	198.98	3	66.32	2.42	
Testings x SES	95.29	3	31.76	1.16	
Testings x Age x Sex	83.50	6	13.91	0.51	
Testings x Age x SES	396.91	6	66.15	2.42	.05
Testings x Sex x SES	29.34	3	9.78	0.36	
Testings x Age x Sex x SES	79.96	6	13.32	0.49	
Error	6896.59	252	27.36		

The Table shows a significant main effect of sex, and mean for this are plotted as Fig 11 Means for interaction between Testings, Age and S.E.S. are also plotted as Fig. 12 since the F.ratio is significant. Trend Analysis of Testings is given as Table 23, and of Interaction between Testings and Age and Table 24.

Fig 11 Spontaneous Alternation - Main effect of Sex

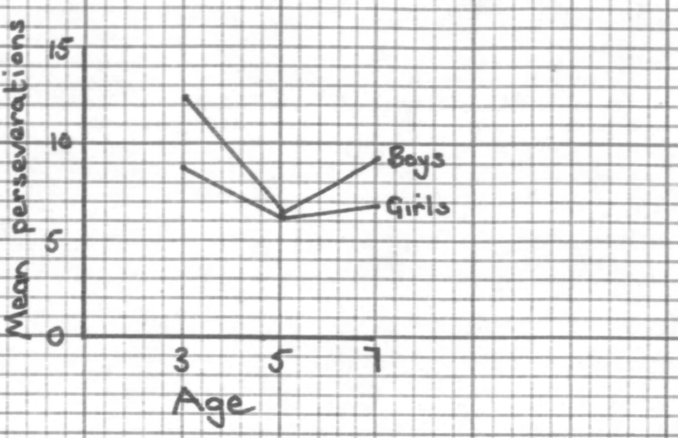


Fig 12 Interaction - Testings × Age × S.E.S Spontaneous Interaction

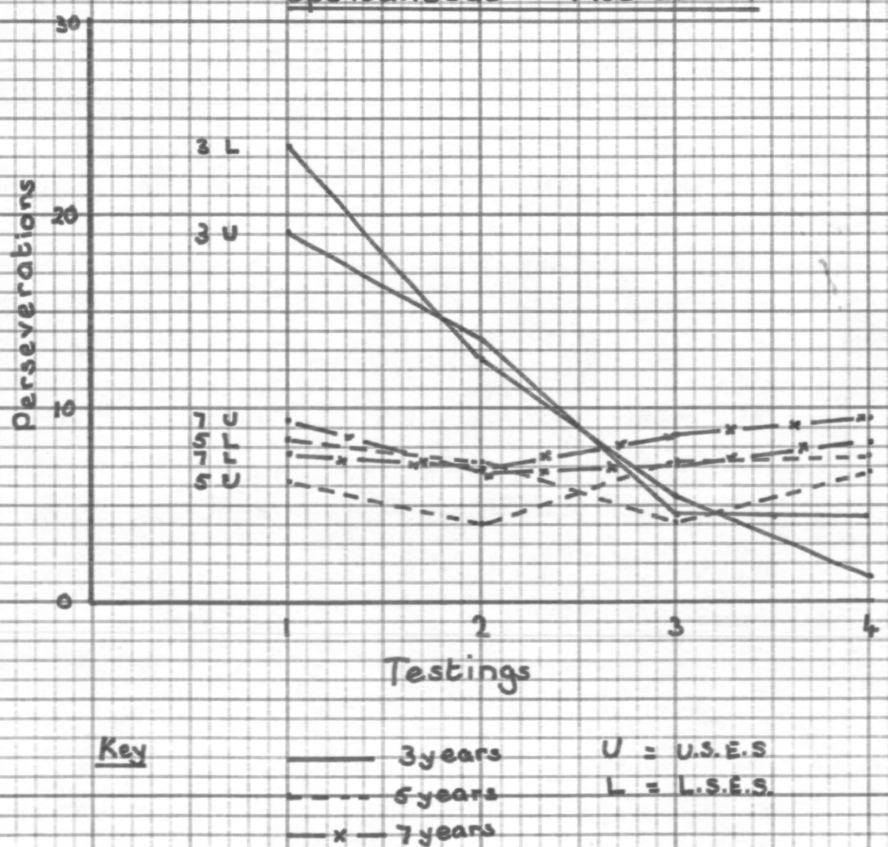


Table 23 Analysis of Trend Spontaneous Alternation

Source	S.S	df	M.S	F.ratio	Sig.Level
Within Treatments	2455.13				
Linear Trend	2064.62	1	2064.62	58.94	.001
Quadratic Trend	386.00	1	386.00	15.49	.001
Other non-linear Trend	4.50	1	4.50	0.20	

Table 24 Analysis of Trend - Interaction between Testings and Age Spontaneous Alternation

Source	S.S	df	M.S	F.ratio	Sig.Level
Within-TestingsxAge	4482.01				
Linear Trend	4365.21	2	2182.60	62.31	.001
Non-Linear Trend					
Quadratic	58.00	2	29.00	1.16	
Cubic	58.80	2	29.40	1.33	

Table 25 Four-Way Analysis of Variance - Oddity Problem

Source	Sum of Squares	df	Mean Square	Fratio	Sig. level
Between					
Age	3084.48	2	1542.24	40.39	0.001
Sex	66.66	1	66.66	1.75	
SES	41.34	1	41.34	1.08	
Age x Sex	74.41	2	37.20	0.97	
Age x SES	38.95	2	19.47	0.51	
Sex x SES	0.09	1	0.09	0.00	
Age x Sex x SES	33.79	2	16.89	0.44	
Error	3207.37	84	38.18		
Within					
Testings	1163.18	3	387.72	16.06	0.001
Testings x Age	947.57	6	157.92	6.54	0.01
Testings x Sex	9.31	3	3.10	0.13	
Testings x SES	16.76	3	5.58	.23	
Testings x Age x Sex	39.60	6	6.60	0.27	
Testings x Age x SES	156.19	6	26.03	1.08	
Testings x Sex x SES	95.42	3	31.80	1.32	
Testings x Age x Sex x SES	87.80	6	14.63	0.61	
Error	6084.62	252	24.14		

Since a significant interaction effect is shown between Age and Testings, means are plotted as Figure 13 before carrying out Trend Analysis for Testings (Table 26) and of the Interaction effect (Table 27).

Fig 13 Interaction - Testings x Age - Oddity Problem

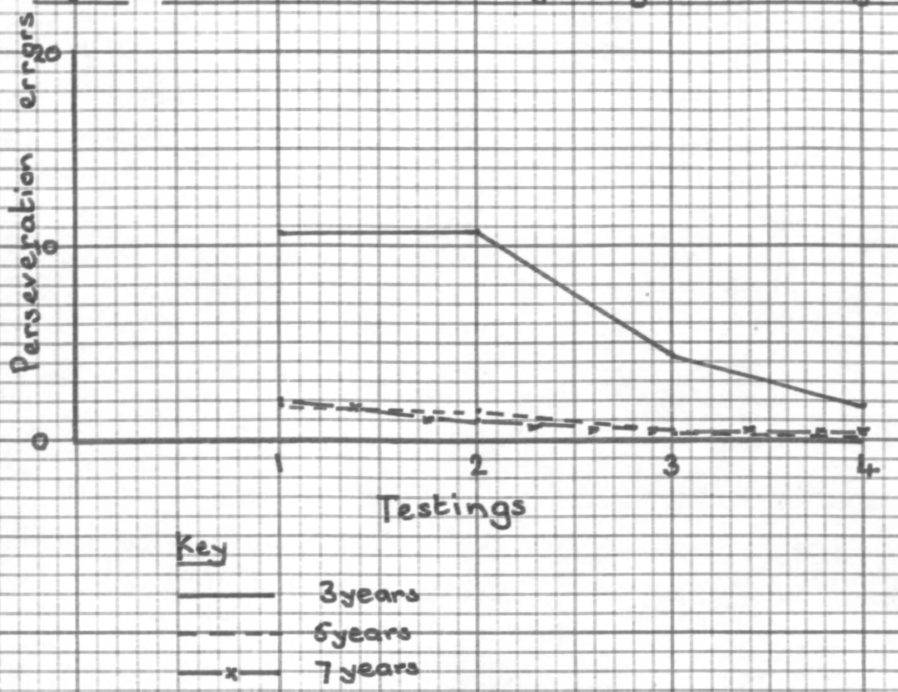


Table 26 Analysis of Trend-Testings - Oddity Problem

Source	S.S	df	M.S	F.ratio	Sig.Level
Within Treatments (testings)	1163.18				
Linear Trend	1059.10	1	1059.10	31.00	.001
Quadratic Trend	4.16	1	4.16	0.21	
Cubic Trend	99.91	1	99.91	5.29	.05

Table 27 Analysis of Trend . Interaction between Age and Task - Oddity Problem

Source	S.S	df	M.S	F.ratio	Sig.Level
Within Treatments x Age	947.57				
Linear Trend	776.70	2	388.35	11.37	0.001
Quadratic Trend	59.31	2	29.65	1.53	
Cubic Trend	111.55	2	55.77	2.95	

Table 28 Four-Way Analysis of Variance - Two-Choice Discrimination Learning Task

Source	Sum of Squares	df	Mean Square	Fratio	Sig. level
Between					
Age	55.82	2	27.91	6.76	.01
Sex	3.96	1	3.96	0.96	
SES	0.31	1	0.31	0.08	
Age x Sex	8.64	2	4.32	1.05	
Age x SES	1.13	2	0.56	0.14	
Sex x SES	0.58	1	0.58	0.14	
Age x Sex x SES	1.42	2	0.71	0.17	
Error	346.71	84	4.12		
Within					
Testings	74.09	3	24.69	5.50	.01
Testings x Age	75.96	6	12.66	2.82	.05
Testings x Sex	3.82	3	1.27	0.28	
Testings x SES	0.25	3	0.08	0.02	
Testings x Age x Sex	9.98	6	1.66	0.37	
Testings x Age x SES	1.20	6	0.20	0.04	
Testings x Sex x SES	15.02	3	5.00	1.12	
Testings x Age x Sex x SES	21.74	6	3.62	0.81	
Error	1130.65	252	4.48		

Means of interaction effect between Testings and Age are plotted as Fig 14, before carrying out **Trend Analysis for Testings** (Table 29) and Interaction between **Testings** and Age (Table 30).

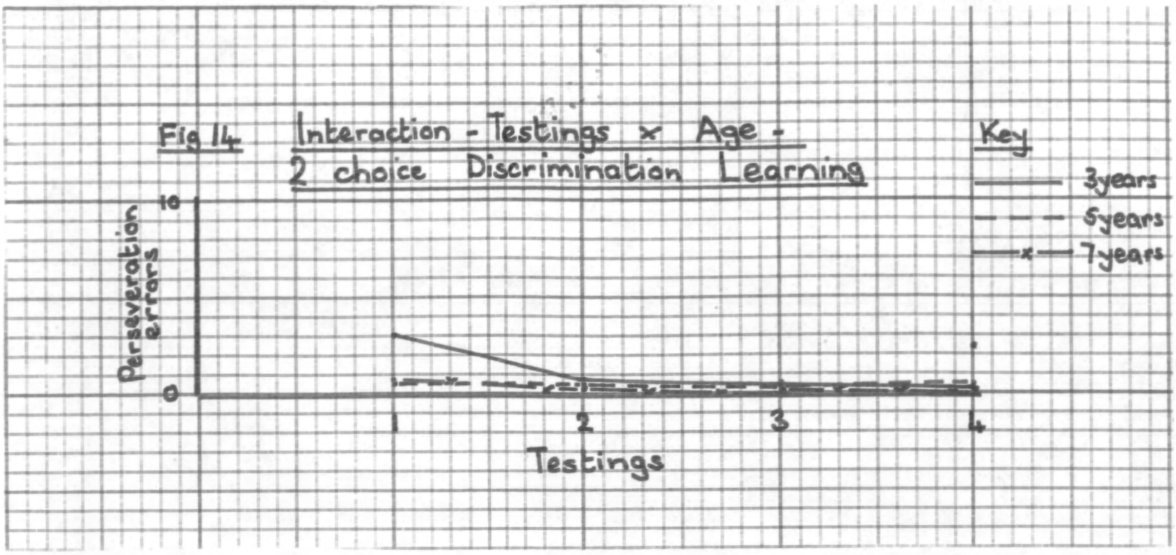


Table 29 Analysis of Trend - Testings
Two-Choice Discrimination Learning Task

Source	S.S	df	M.S	F.ratio	Sig.Level
Within Treatments-Testings	74.09				
Linear Trend	59.15	1	59.15	7.65	.01
Non-Linear					
Quadratic	13.12	1	13.12	3.08	
Cubic	1.81	1	1.81	1.24	

Table 30 Analysis of Trend - Interaction Testings and Age
Two-Choice Discrimination Learning Task

Source	S.S	df	M.S	F.ratio	Sig.Level
Within Testings x Age	75.96				
Linear	58.23	2	29.11	3.76	.05
Non-Linear					
Quadratic	14.28	2	7.14	1.68	
Cubic	3.43	2	1.71	1.17	

Table 31 Four-Way Analysis of Variance - Three Choice Discrimination Learning - 66% Reinforcement Condition

Source	Sum of Squares	df	Mean Square	Fratio	Sig. level
Between					
Age	7263.80	2	3631.95	16.26	0.001
Sex	585.48	1	585.48	2.62	
SES	6.90	1	6.90	0.03	
Age x Sex	335.06	2	167.53	0.75	
Age x SES	50.38	2	25.19	0.11	
Sex x SES	326.91	1	326.91	1.46	
Age x Sex x SES	1263.61	2	631.80	2.83	
Error	8042.43	36	223.40		
Within					
Testings	5765.07	3	1921.69	12.39	.001
Testings x Age	4695.54	6	782.59	5.05	.001
Testings x Sex	446.40	3	148.80	0.96	
Testings x SES	48.31	3	16.10	0.10	
Testings x Age x Sex	61.73	6	10.28	0.07	
Testings x Age x SES	73.16	6	12.19	0.08	
Testings x Sex x SES	463.02	3	154.34	1.00	
Testings x Age x Sex x SES	1044.05	6	174.00	1.12	
Error	16744.64	108	155.04		

Table 31 shows that interaction between age and testings is statistically significant. Means are plotted as Figure 15 - before carrying out Trend Analysis for Testings (Table 32) and of interaction between Age and Testings (Table 33).

Fig 15 Interaction - Testings x Age
3 choice Discrimination Learning
66% Reinforcement Condition

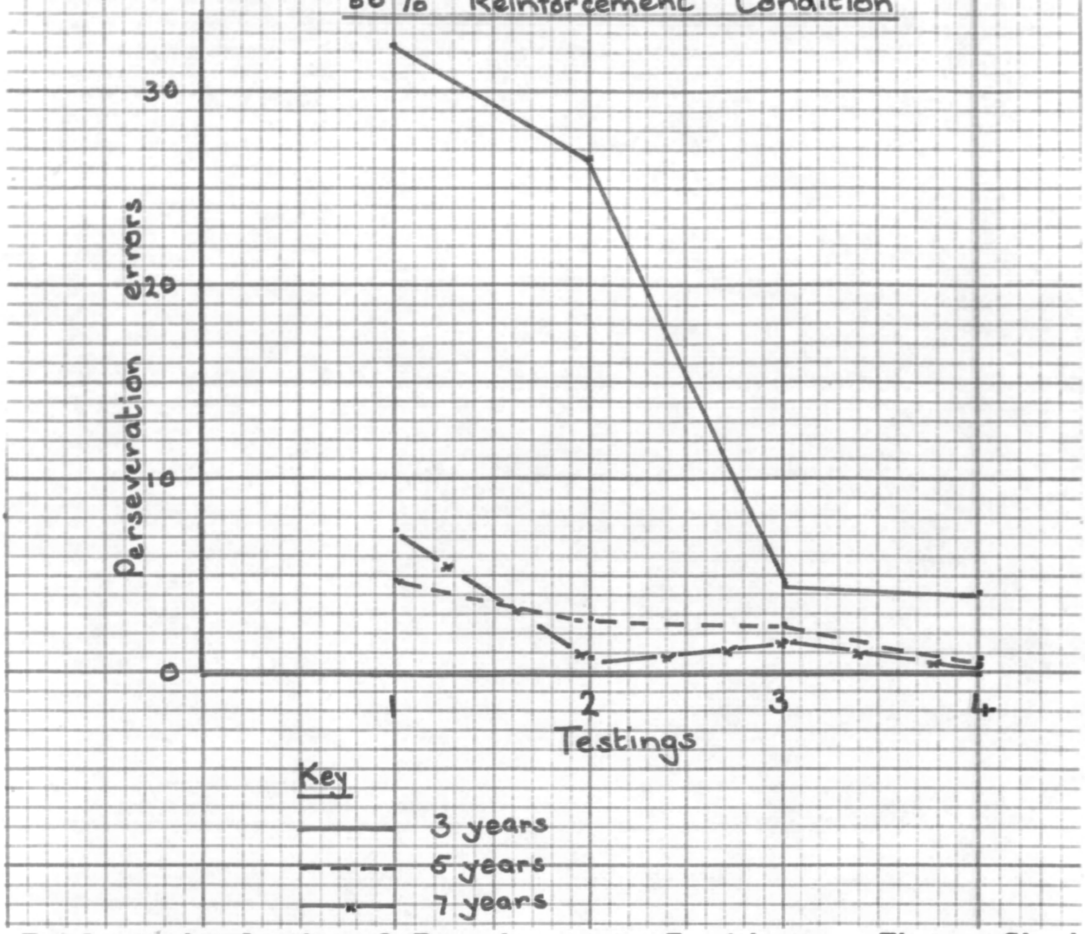


Table 32 Analysis of Trend Testings - Three Choice Discrimination - 66% Reinforcement Condition

Source	S.S	df	M.S	F.ratio	Sig. Level
Within Treatments-Testings	5765.07				
Linear Trend	5399.55	1	5399.55	23.22	0.001
Non-Linear Trend					
Quadratic	242.73	1	242.73	1.57	
Cubic	122.78	1	122.78	1.58	

Table 33 Analysis of Trend - Interaction Testings and Age Three Choice Discrimination Learning 66% Reinforcement Condition

Source	S.S	df	M.S	F.ratio	Sig. Level
Within Treatment x Age	4695.54				
Linear Trend	3701.07	2	1850.53	7.96	.01
Non-Linear Trend					
Quadratic	1.90	2	0.95	0.01	
Cubic	992.56	2	496.28	6.40	.01

Table 34 Four-Way Analysis of Variance - Three-choice Discrimination Learning
33% Reinforcement Condition

Source	Sum of Squares	df	Mean Square	Fratio	Sig. level
Between					
Age	12874.08	2	6437.04	33.87	0.001
Sex	58.33	1	58.33	0.31	
SES	173.77	1	173.77	0.91	
Age x Sex	118.92	2	59.46	0.31	
Age x SES	398.79	2	199.39	1.05	
Sex x SES	126.84	1	126.84	0.67	
Age x Sex x SES	628.48	2	314.24	1.65	
Error	6842.40	36	190.06		
Within					
Testings	3505.40	3	1168.46	12.81	0.001
Testings x Age	4092.83	6	682.13	7.48	0.001
Testings x Sex	205.23	3	68.41	0.75	
Testings x SES	390.53	3	130.17	1.43	
Testings x Age x Sex	420.01	6	70.00	0.77	
Testings x Age x SES	300.22	6	50.03	0.55	
Testings x Sex x SES	245.89	3	81.96	0.90	
Testings x Age x Sex x SES	1254.32	6	209.05	2.29	.05
Error	9850.34	108	91.20		

Table34shows that there is a significant two-way interaction between Testings and Age, and a four-way interaction between Testing, Age x Sex and S.E.S. Means for the two-way interaction are plotted as Figure 16 and in tree diagram form for the four-way interaction (Figure 17) These are followed by Table 35 Trend Analysis for Testings and Table 36 Interaction between Testings and Age.

Fig 16 Interaction - Testings x Age - 3 choice Discrimination Learning - 33% Reinforcement Condition

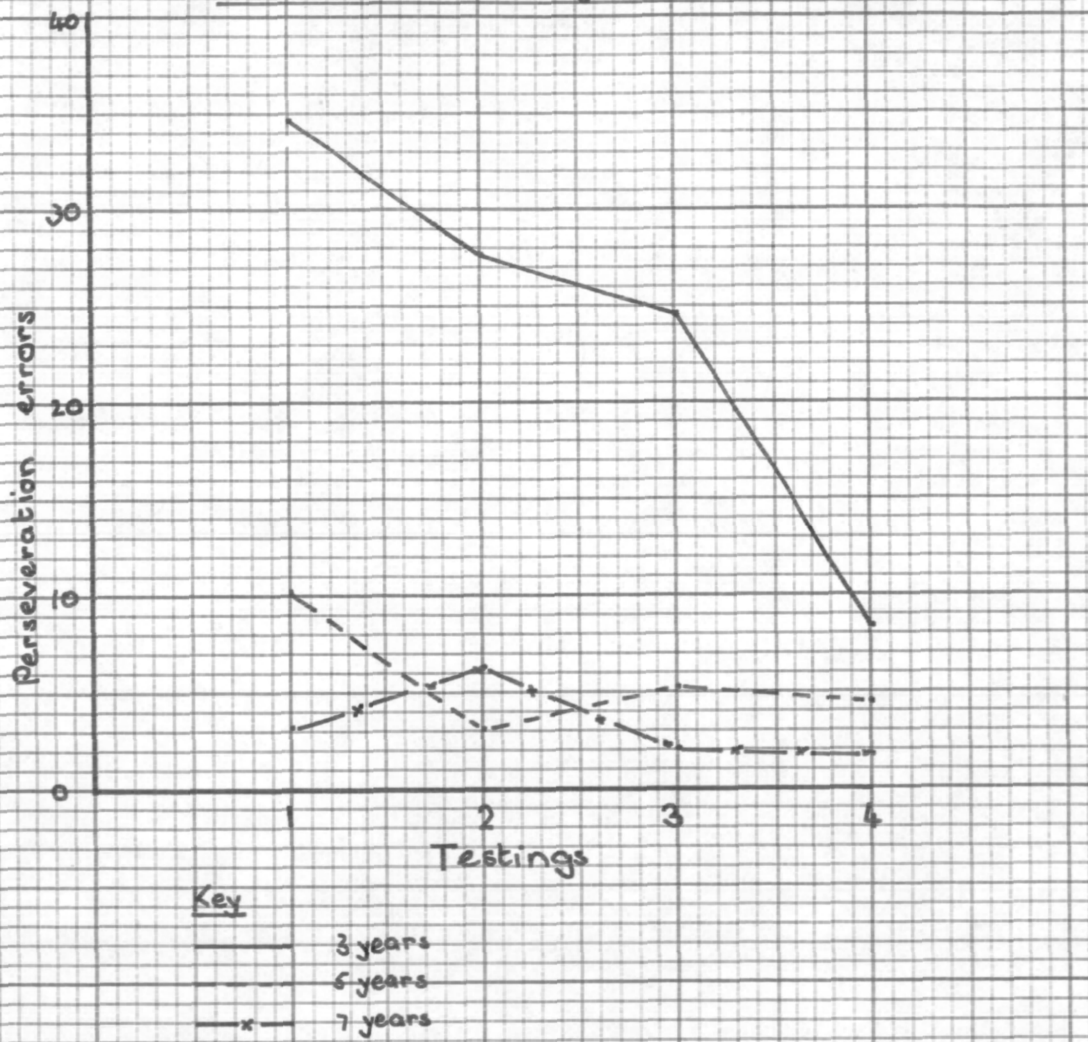


Fig 17 Four-Way Interaction - Testings x Age x Sex x SES
Three Choice Discrimination Learning
33% Reinforcement Condition

Age						
3 years	BOYS	USES	47.75	20.0	15.5	6.0
		LSES	30.0	38.67	5.3	13.0
	GIRLS	USES	24.8	24.0	7.0	6.6
		LSES	38.0	36.0	30.5	9.0
5 years	BOYS	USES	4.0	2.0	.33	4.7
		LSES	8.33	4.0	2.33	3.3
	GIRLS	USES	15.2	1.8	9.6	6.8
		LSES	9.8	4.4	5.6	3.2
7 years	BOYS	USES	2.67	6.0	3.0	2.33
		LSES	4.33	5.0	1.67	1.67
	GIRLS	USES	3.4	3.4	2.6	2.6
		LSES	2.6	10.2	1.2	.8

Table 35 Analysis of Trend - Testings
Three Choice Discrimination Learning -
33% Reinforcement Condition

Source	S.S	df	M.S	F.ratio	Sig. Level
Within Testings	3505.40				
Linear Trend	3391.35	1	3391.35	42.71	0.001
Non-Linear Trend					
Quadratic	9.12	1	9.12	0.09	
Cubic	104.92	1	104.92	1.15	

Table 36 Analysis of Trend - Interaction between Testings
and Age - Three Choice Discrimination
33% Reinforcement Condition

Source	S.S	df	M.S	F.ratio	Sig.Level
Within Testings x Age	4092.83				
Linear Trend	3602.24	2	1801.12	22.68	0.001
Non-Linear Trend					
Quadratic	179.22	2	89.61	0.87	
Cubic	311.37	2	155.68	1.70	

Table 37 Four-Way Analysis of Variance - Attributes Task

Source	Sum of Squares	df	Mean Square	Fratio	Sig. level
Between					
Age	3474.44	2	1737.22	20.94	0.001
Sex	16.25	1	16.25	0.20	
SES	35.66	1	35.64	0.43	
Age x Sex	40.41	2	20.20	0.24	
Age x SES	77.39	2	38.69	0.47	
Sex x SES	107.31	1	107.31	1.29	
Age x Sex x SES	74.75	2	37.37	0.45	
Error	6970.03	84	82.97		
Within					
Testings	4130.02	3	1376.67	29.84	0.001
Testings x Age	850.24	6	141.70	3.07	0.01
Testings x Sex	86.27	3	28.75	0.62	
Testings x SES	115.34	3	38.44	0.83	
Testings x Age x Sex	346.40	6	57.73	1.25	
Testings x Age x SES	258.71	6	43.11	0.93	
Testings x Sex x SES	303.84	3	101.28	2.20	
Testings x Age x Sex x SES	356.55	6	59.42	1.29	
Error	11624.34	252	46.12		

Table 37 shows a significant interaction between Testings and Age. Means are therefore plotted for these variables as Figure 18 before carrying out Trend Analysis for Testings (Table 38) and Testings x Age (Table 39).

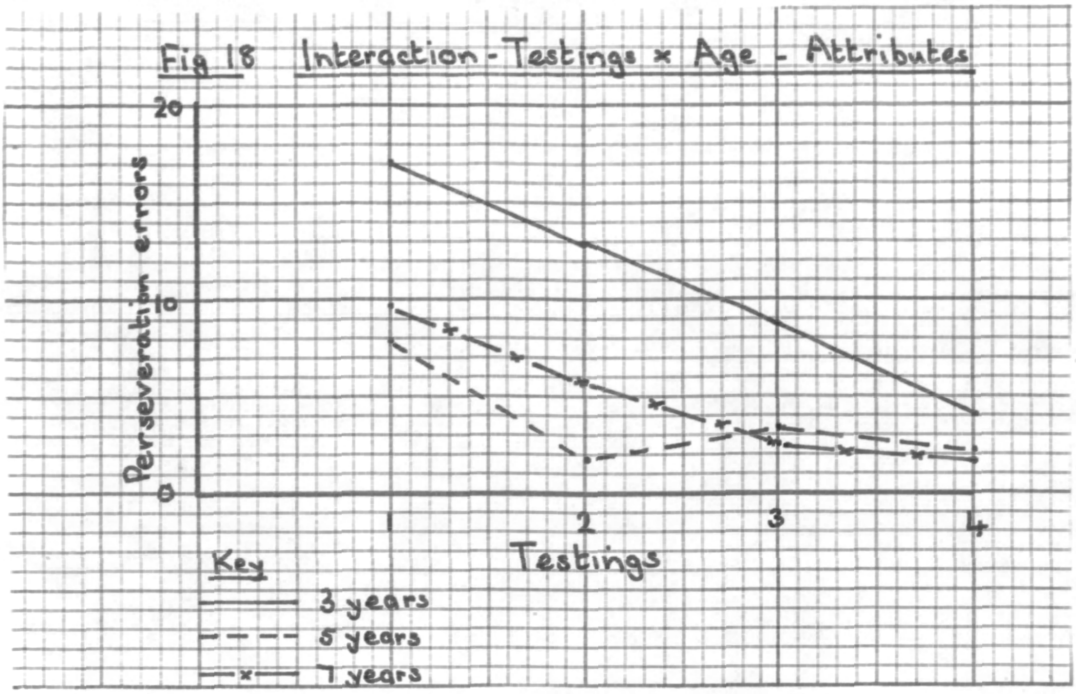


Table 38 Analysis of Trend Testings - Attributes Task

Source	S.S	df	M.S	F.ratio	Sig.Level
Within Treatment	4130.02				
Linear Trend	3930.21	1	3930.21	62.54	0.001
Non-Linear Trend					
Quadratic	156.31	1	156.31	3.57	
Cubic	43.50	1	43.50	1.37	

Table 39 Analysis of Trend - Interaction Testings and Age - Attributes Task

Source	S.S	df	M.S	F.ratio	Sig. Level
Within Treatment x Age	850.24				
Linear Trend	586.41	2	293.20	4.67	0.05
Non Linear Trend					
Quadratic	130.00	2	65.00	1.48	
Cubic	133.81	2	66.90	2.11	

Four-Way Analysis of Variance - Arc-Sine Transformation of Proportion of perseveration errors or score

The preceding ANOVA's and related Trend Analysis have shown age to be a main effect in reduction of perseveration behaviour on each of the experimental tasks. However, as it can be expected that errors will decline over age, it is likely that with this, perseverations similarly will decline. It does not follow, though that perseverations remain as a constant proportion of total errors or, in the case of Spontaneous Alternation, of total trials. By deriving proportions of perseverations to total errors for all tasks, except for Spontaneous Alternation where total trials were used, it was possible to determine whether the proportion of perseverations remained constant or varies as a function of age or task. The literature reviewed in Chapter 1 has suggested that an alternation strategy emerges from about four years of age across a wide variety of tasks. A decline in the proportion of perseverations therefore indicates an increase in alternation, since errors were categorised as either the one or the other.

The use of proportions additionally makes possible a comparison between perseverations obtained from the six experimental tasks which, for methodological reasons, arising from the selection of the tasks, differed in the number of trials possible, and therefore, error totals. For purposes of analysis, arc-sine transformations were derived from each proportion score (Edwards 1968) and used as the dependent variables. This technique normalises variance, and thus allows for statistical testing by ANOVA.

Four-Way Analysis of Variance were carried out for each of the experimental tasks, using the BMDP 2V computer programme, as for the series of ANOVAs reported on pages 183, 185, 188 189, 192, 196 of this Chapter, and with age, sex and social class as independent variables. With the exception of results from analysis of Two-Choice Discrimination Learning Task, results of the ANOVAs are consistent with those obtained from analysis of raw perseveration scores. All the results are nevertheless presented (Tables 40, 42, 45, 46, 49, 52. The Trend Analyses (Tables 41, 43, 44, 37, 48, 50, 51) are also given since they have important implications for the research

Table 40 Four-Way A NOVA - Wisconsin Card Sorting Test - Arc sine Transformation of Perseverative errors to otal errors

Source	Sum of Squares	df	Mean Square	Fratio	Sig. level
Between					
Age	5021.39	2	2510.69	27.57	0.001
Sex	44.34	1	44.34	0.49	
SES	382.54	1	382.54	4.20	.05
Age x Sex	365.96	2	182.98	2.01	
Age x SES	141.49	2	70.74	0.78	
Sex x SES	75.57	1	75.57	0.83	
Age x Sex x SES	680.99	2	340.49	3.74	.05
Error	7650.31	84			
Within					
Testings	547.64	3	182.54	3.06	.05
Testings x Age	256.13	6	42.68	0.72	
Testings x Sex	100.84	3	33.61	0.56	
Testings x SES	426.61	3	142.20	2.39	
Testings x Age x Sex	584.25	6	97.37	1.63	
Testings x Age x SES	464.88	6	77.48	1.30	
Testings x Sex x SES	20.61	3	6.87	0.12	
Testings x Age x Sex x SES	383.07	6	63.84	1.07	
Error	15022.86	252	59.61		

Since Table 40 shows a significant interaction between main effects of Age, Sex and SES, means for these are plotted as Figure 19, before carrying out Trend Analysis for Testings (Table 41).

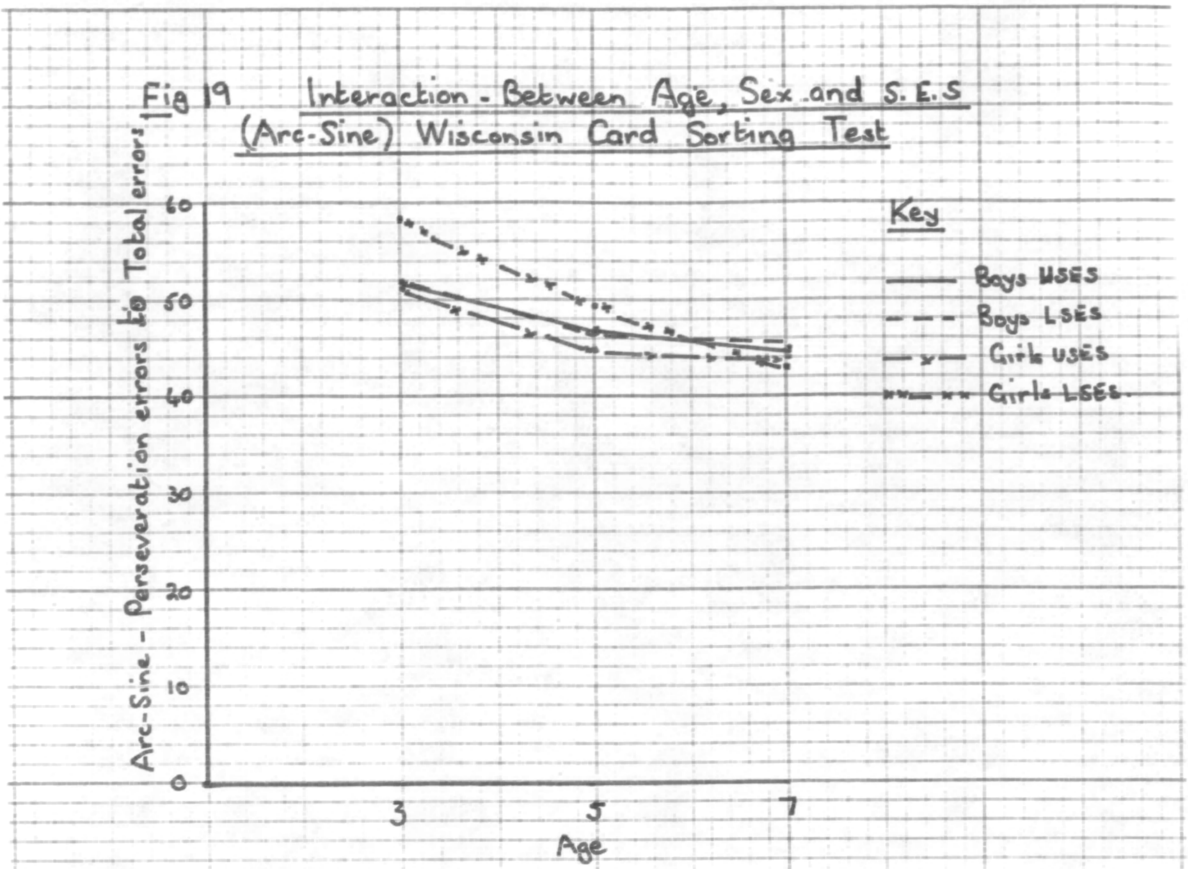


Table 41 Analysis of Trend Testings - Wisconsin Card Sorting Test (Arc-sine Transformation of Perseverative errors to Total errors)

Source	S.S	df	M.S	F.ratio	Sig.Level
Within Testings	547.64				
Linear Trend	318.28	1	318.28	6.64	.05
Non-Linear Trend					
Quadratic	34.35	1	34.35	0.55	
Cubic	195.01	1	195.01	2.83	

Table 42 Four-Way ANOVA - Spontaneous Alternation - Arc-Sine Transformation of Perseverations to Total trials

Source	Sum of Squares	df	Mean Square	Fratio	Sig. level
Between					
Age	5521.14	2	2760.57	6.01	.01
Sex	2330.41	1	2330.46	5.08	.05
SES	151.56	1	151.56	0.33	
Age x Sex	1304.66	2	652.33	1.42	
Age x SES	104.88	2	52.44	0.11	
Sex x SES	508.96	1	508.96	1.11	
Age x Sex x SES	113.42	2	56.71	0.12	
Error	38565.21	84	459.10		
Within					
Testings	18276.53	3	6092 .17	28.74	0.001
Testings x Age	32273.06	6	5378.84	25.37	0.001
Testings x Sex	1473.95	3	491.31	2.32	
Testings x SES	848.76	3	282.92	1.33	
Testings x Age x Sex	483.19	6	80.53	0.38	
Testings x Age x SES	3657.38	6	609.56	2.88	.01
Testings x Sex x SES	318.64	3	106.21	0.50	
Testings x Age x Sex x SES	1017.51	6	169.58	0.80	
Error	53417.67	252	211.97		

Fig 21 Linear and Non-Linear Trends (Arc-Sine) - Spontaneous Alternation

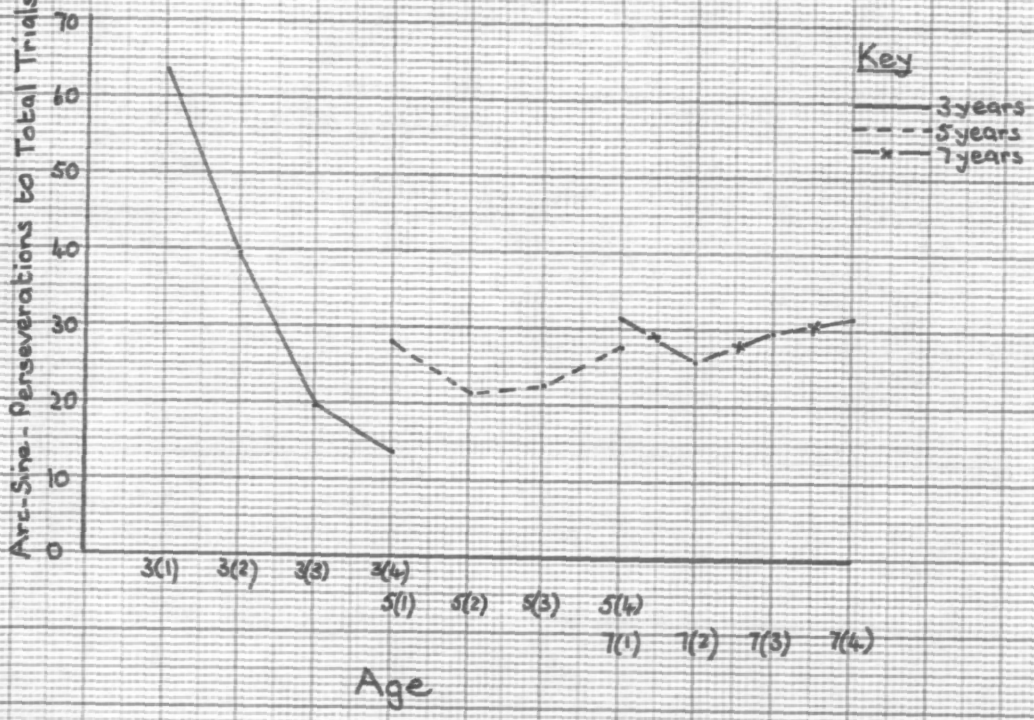


Table 42 shows significant interactions between Testings and Age, and Testings, Age and S.E.S. in addition to main effects of age and Sex. Means for the three-way interaction are plotted as Figure 20 and shown on page194 of this Chapter, together with Figures 23, 24 for ease of visual comparison. Trend Analysis is carried out for Testings (Table 43) and for interaction of Testings with Age (Table 44). Trends for Testings are additionally plotted as Figure 21 in view of the significant linear and non-linear trends.

Table 43 Analysis of Trend - Testings Spontaneous Alternation- Arc-sine Transformation - Perseverations to Total trials

Source	S.S	df	M.S	F.ratio	Sig.Level
Within Testings	18276.53				
Linear Trend	14608.18	1	14608.18	55.73	0.001
Non-Linear Trend					
Quadratic	3654.05	1	3654.05	17.81	0.001
Cubic	14.29	1	14.29	0.08	

Table 44 Analysis of Trend - Interaction Testings with Age Spontaneous Alternation Arc-sine transformations of Perseverations to Total Trials

Source	S.S	df	M.S	F.ratio	Sig.Level
Within Testings X Age	32273.06				
Linear Trend	31505.14	2	15752.57	60.10	0.001
Non-Linear Trend					
Quadratic	409.24	2	204.62	1.00	
Cubic	358.67	2	179.33	1.06	

Table 45 Four-Way ANOVA – Oddity problem - Arc-sine Transformation of Perseverative errors to Total errors

Source	Sum of Squares	df	Mean Square	Fratio	Sig. level
Between					
Age	18141.31	2	9070.65	12.76	0.001
Sex	11.62	1	11.62	0.02	
SES	264.68	1	264.68	0.37	
Age x Sex	959.93	2	479.96	0.68	
Age x SES	2172.19	2	1086.09	1.53	
Sex x SES	108.68	1	108.68	0.15	
Age x Sex x SES	1319.12	2	659.56	0.93	
Error	59710.58	84	710.84		
Within					
Testings	3317.00	3	1105.66	2.27	
Testings x Age	1887.37	6	314.56	0.65	
Testings x Sex	301.58	3	100.52	0.21	
Testings x SES	1215.05	3	405.01	0.83	
Testings x Age x Sex	2428.72	6	404.78	0.83	
Testings x Age x SES	4876.85	6	812.80	1.67	
Testings x Sex x SES	2591.85	3	863.95	1.77	
Testings x Age x Sex x SES	2748.25	6	458.04	0.94	
Error	122778.69	252	487.21		

Two-Choice Discrimination Learning - Arc-Sine Transformations of Perseverative to Total Errors

Four-way ANOVA carried out for perseverative to total errors made on Two-Choice Discrimination Learning Task gave non-significant results on all between and within factors. No Table is therefore presented.

Table 46 Four-Way ANOVA - Three-Choice Discrimination Learning Task
Arc-sine Transformation of Perseverative errors to Total errors
66% Reinforcement condition

Source	Sum of Squares	df	Mean Square	Fratio	Sig. level
Between					
Age	14292.70	2	7146.35	21.94	0.001
Sex	2255.81	1	2255.81	6.93	0.05
SES	3.30	1	3.30	0.01	
Age x Sex	1137.06	2	568.53	1.75	
Age x SES	556.70	2	278.35	0.85	
Sex x SES	149.65	1	149.65	0.46	
Age x Sex x SES	1628.62	2	814.31	2.50	
Error	11724.40	36	325.67		
Within					
Testings	9485.50	3	3161.83	15.32	0.001
Testings x Age	3574.01	6	595.66	2.89	0.05
Testings x Sex	466.63	3	155.54	0.75	
Testings x SES	428.22	3	142.74	0.69	
Testings x Age x Sex	597.52	6	99.58	0.48	
Testings x Age x SES	487.14	6	81.19	0.39	
Testings x Sex x SES	797.75	3	265.91	1.29	
Testings x Age x Sex x SES	1188.98	6	198.16	0.96	
Error	22285.84	108	206.35		

Table 46 shows a significant interaction of Testings with Age in the 66% Reinforcement Condition of the Three-Choice Discrimination Learning Task. Means are plotted as Figure 23 , and shown on page 195 to enable visual comparison with related figures to be made. Trend Analysis for Testings is shown as Table 47 , and for Interaction of Testings with Age as Table 48 Means for main effect of sex are plotted as Figure 22

Table 47 Analysis of Trend - Testings Three Choice Discrimination Learning (66% reinforcement condition) - Arc-sine Transformation of Perseverative to Total errors

Source	S.S	df	M.S	F.ratio	Sig.Level
Within Testings	9485.50				
Linear Trend	9104.55	1	9104.55	37.11	.001
Non-Linear Trend					
Quadratic	380.79	1	380.79	1.84	
Cubic	0.16	1	0.16	0.00	

Table 48 Analysis of Trend - Interaction Testings with Age Three Choice Discrimination Learning (66% reinforcement) Arc-sine Transformation of Perseverative to Total errors

Source	S.S	df	M.S	F.ratio	Sig.Level
Within Testings x Age	3574.01				
Linear Trend	2086.56	2	1043.28	4.25	0.05
Non-Linear Trend					
Quadratic	274.47	2	137.23	0.66	
Cubic	1212.97	2	606.48	3.64	0.05

Fig 22 3 choice Discrimination Learning - 66%
Main effect of Sex (Arc-sine)

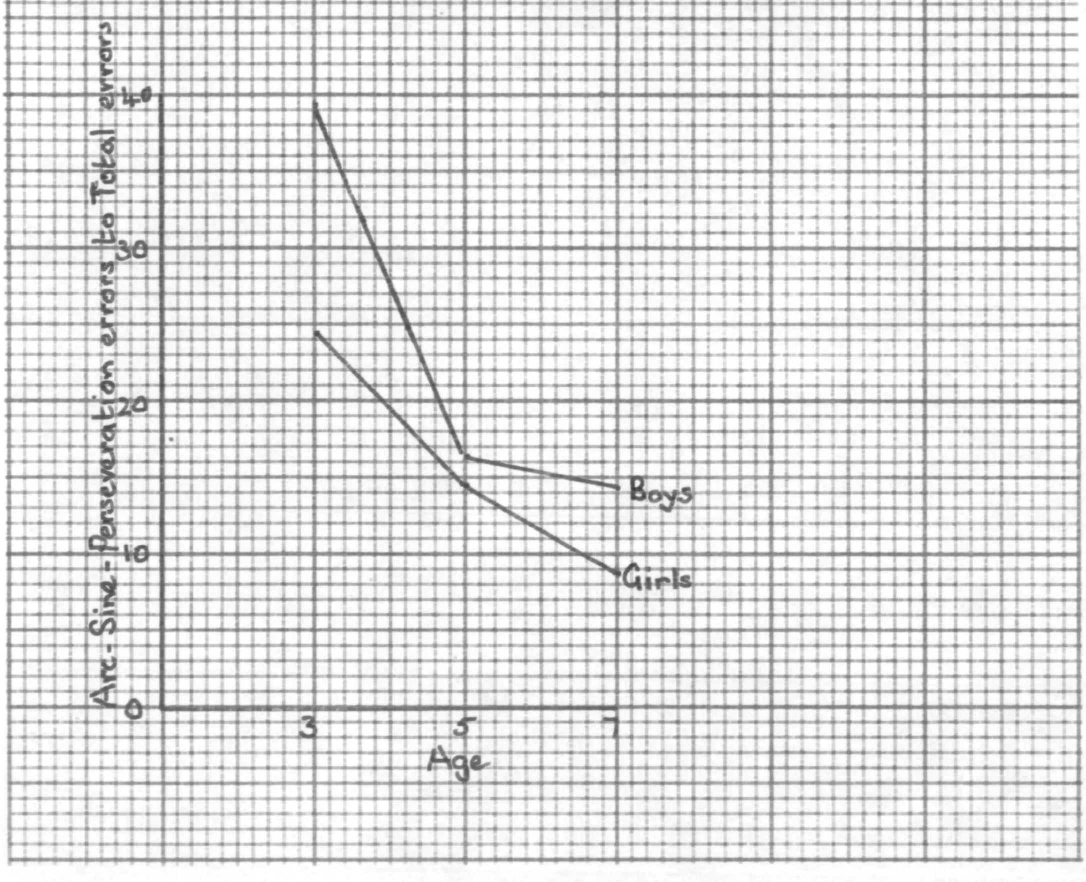


Table 49 Four-Way ANOVA - Three Choice Discrimination Learning (33% Reinforcement Condition) Arc-sine Transformation of Perseverative errors to Total errors

Source	Sum of Squares	df	Mean Square	Fratio	Sig. level
Between					
Age	21411.82	2	10705.95	48.96	0.001
Sex	29.62	1	29.62	0.14	
SES	39.43	1	39.43	0.18	
Age x Sex	389.89	2	194.94	0.89	
Age x SES	55.68	2	27.84	0.13	
Sex x SES	1.26	1	1.26	0.01	
Age x Sex x SES	1163.08	2	581.54	2.66	
Error	7872.67	36	218.68		
Within					
Testings	4498.36	3	1499.45	10.22	0.001
Testings x Age	4419.43	6	736.57	5.02	0.001
Testings x Sex	622.20	3	207.40	1.41	
Testings x SES	386.21	3	128.73	0.88	
Testings x Age x Sex	589.61	6	98.26	0.67	
Testings x Age x SES	546.89	6	91.14	0.62	
Testings x Sex x SES	569.72	3	189.90	1.29	
Testings x Age x Sex x SES	1067.73	6	177.95	1.21	
Error	15838.15	108	146.64		

Table 49 shows a significant interaction of Testings with Age on the 33% Reinforcement Condition of the Three-Choice Discrimination Learning Task. Means for these are plotted, and are shown on page 195 as Figure 24 together with related figures. Trend Analysis is carried out for Testings (Table 50) and for Interaction between Testings and Age (Table 51)

Table 50 Analysis of Trend Testings on Three Choice Discrimination Learning
Arc-sine Transformation of Perseverative to Total errors (33% Reinforcement condition)

Source	S.S	df	M.S	F.ratio	Sig.Level
Within Testings	4498.36				
Linear Trend	4224.51	1	4224.51	20.46	0.001
Non-Linear Trend					
Quadratic	53.76	1	53.76	0.48	
Cubic	220.08	1	220.08	1.83	

Table 51 Analysis of Trend - Interaction Testings and Age - Three Choice Discrimination Learning - Arc-sine Transformation of Perseverative to Total errors (33% Reinforcement condition)

Source	S.S	df	M.S	F.ratio	Sig.Level
Within Testings x Age	4419.43				
Linear Trend	2806.14	2	1403.07	6.80	0.01
Non-Linear Trend					
Quadratic	954.03	2	477.01	4.22	0.05
Cubic	659.26	2	329.63	2.73	

From the preceding ANOVAs, using transformed data, Figures 20, 23 and 24 are presented in sequence to enable visual comparison to be made. The use of Arc-sine transformation on the data derived from proportions of perseveration to total errors (scores and trials - Spontaneous Alternation) has given comparability across tasks.

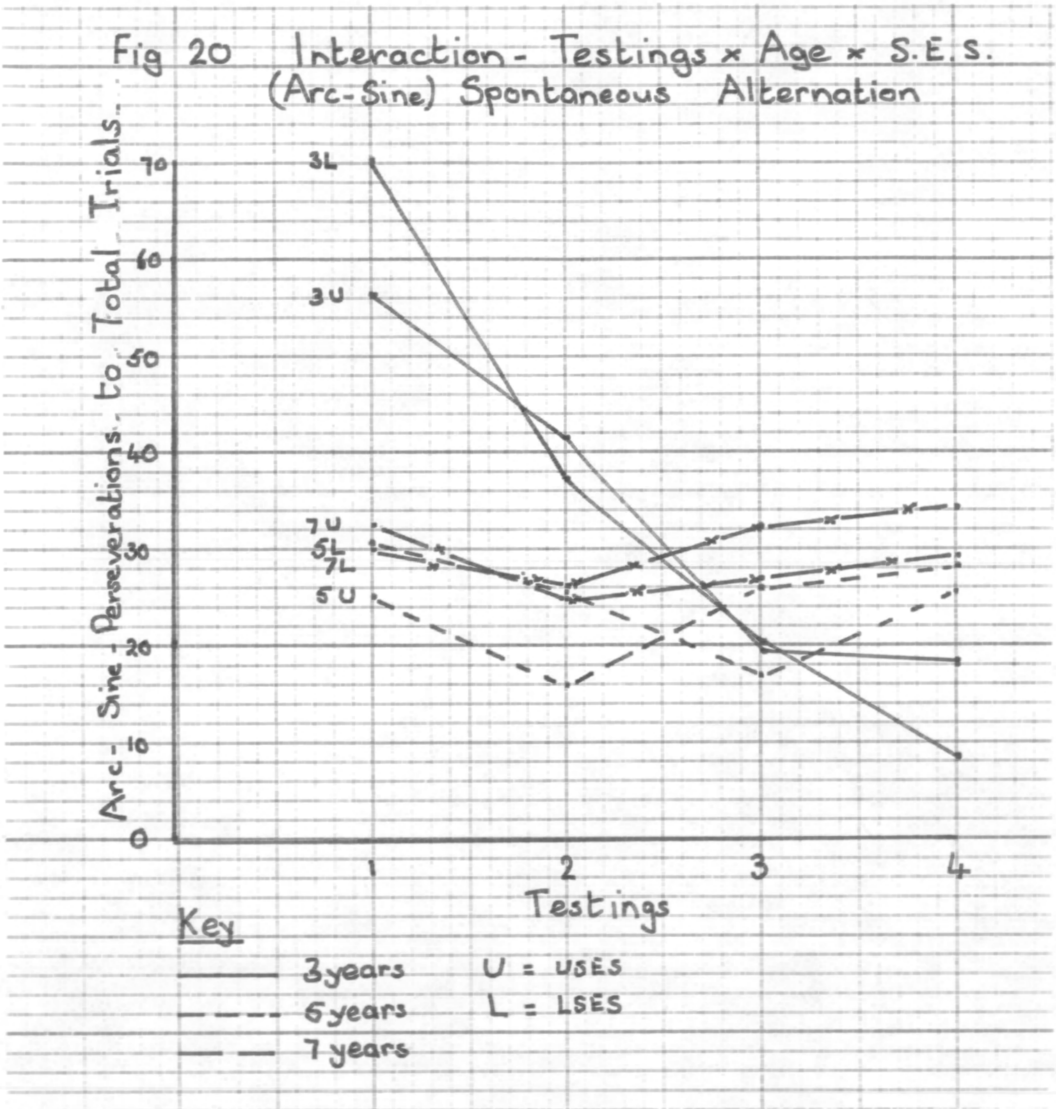


Fig 23 Interaction - Testings × Age - (Arc - Sine) 3 choice Discrimination Learning - 66% Reinforcement Condition

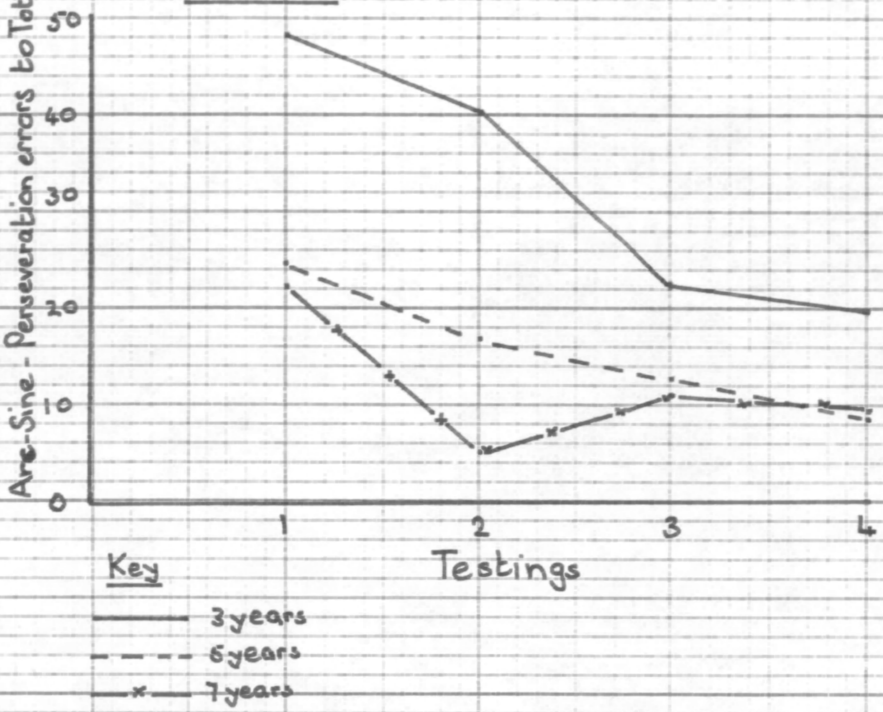


Fig 24 Interaction - Testings × Age (Arc - Sine) 3 choice Discrimination Learning - 33% Reinforcement Condition

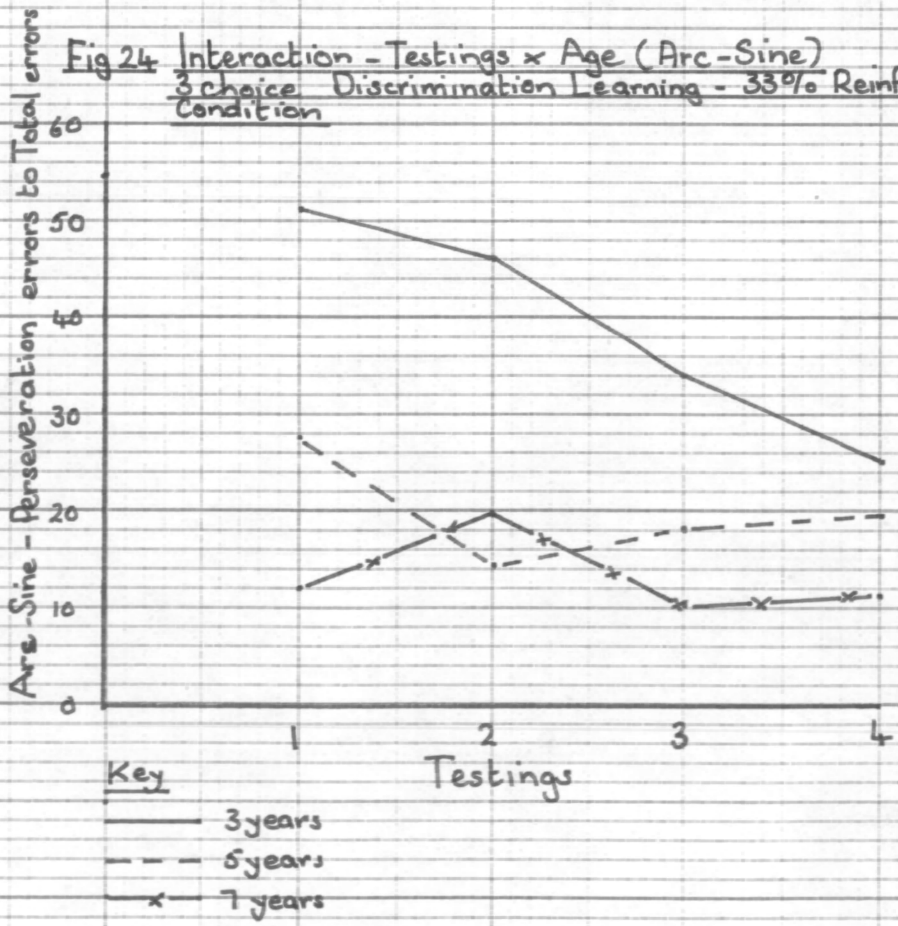


Table 52 Four-Way ANOVA Attributes - Arc-sine Transformations of Perseverative errors to Total errors

Source	Sum of Squares	df	Mean Square	Fratio	Sig. level
Between					
Age	19924.46	2	9962.23	15.53	0.001
Sex	463.10	1	463.10	0.72	
SES	27.13	1	27.13	0.04	
Age x Sex	1063.31	2	531.65	0.83	
Age x SES	279.02	2	139.51	0.22	
Sex x SES	2.38	1	2.38	0.00	
Age x Sex x SES	136.63	2	68.31	0.11	
Error	53874.24	84	641.36		
Within					
Testings	2496.29	3	832.09	1.50	
Testings x Age	5782.46	6	963.74	1.74	
Testings x Sex	1136.93	3	378.97	0.68	
Testings x SES	1202.26	3	400.75	0.72	
Testings x Age x Sex	1824.30	6	304.05	0.55	
Testings x Age x SES	5668.31	6	944.71	1.70	
Testings x Sex x SES	2480.13	3	826.71	1.49	
Testings x Age x Sex x SES	8202.861	6	1367.14	2.47	0.05
Error	139711.74	252	554.41		

Since Table52 shows a significant four-way interaction between Testings, Age, Sex and SES, means for these are given as a tree diagram (Figure 25).

Fig 25 Four-Way Interaction - Testings x Agex Sex x SES - Attributes (Arc-sine)

Age	Sex	SES	Testings			
3 years	BOYS	USES	50.6	43.49	53.22	47.39
		LSES	51.87	55.29	51.24	34.04
	GIRLS	USES	46.96	40.64	43.46	42.88
		LSES	47.59	47.85	50.05	37.55
5 years	BOYS	USES	22.67	29.28	32.10	26.85
		LSES	46.73	14.34	21.05	32.42
	GIRLS	USES	49.45	9.51	38.5	24.88
		LSES	33.90	29.64	31.70	27.31
7 Years	BOYS	USES	42.70	48.95	42.34	46.17
		LSES	53.82	49.39	22.92	48.16
	GIRLS	USES	33.82	63.58	37.88	29.72
		LSES	40.37	22.58	42.65	41.83

Analysis of Within Task Differences

Following the major analyses of Principal Components Factor Analyses, and Four-Way Analysis of Variance of raw perseveration scores, and, separately, Arc-sine Transformations of proportions of perseverations to errors (trials for Spontaneous Alternation), the results of which are reported in the preceding pages of this chapter, minor analyses are carried out to test for differences within three of the experimental tasks. These are the Wisconsin Card Sorting Test, the Two choice Discrimination Learning Task, and the Three Choice Discrimination Learning Task, each of which appears to contain differences in cognitive demand.

Each Within Task Analysis is reported separately, and in relation to the appropriate null hypotheses.

Wisconsin Card Sorting Test

This task is fully described in Chapter 3, page 126 but it is noted here, for reasons of clarity, that in achieving each successive category, continued response to a previously correct category must be inhibited. For the purposes of the main analyses, all perseverative errors made by each child within a testing were pooled, irrespective of the number of categories achieved. It is, however, of interest to the investigation to test for differences between total and perseverative errors made in achieving categories. Stated in the null form (i, ii, iii, p118 chapter 2) it was hypothesised that there would be no difference in perseverative errors or number of trials between age levels, nor within children on each of the four test occasions, in attaining three categories on this task.

The total error scores for each category made by children who completed three categories were used as the dependent variable for computation of one way ANOVA (Repeated Measures) for each testing. Results are presented as Tables 53,54,55,56,57 A significance level of .05 is considered sufficient to reject the null hypothesis.

It should be noted that results shown for Testings 1, 2 and 3 are obtained from analysis of 7 year old children's scores only. No 3 year olds achieved three categories at Testing 1 and only two 5 year olds did so. For Testings 2, 3 and 4 one 3 year old was successful, and the number of 5 year olds increased (four at Testing 2, five at Testing 3, three at Testing 4). Separate ANOVAs were computed for the 5 year old and 7 year old successful sub samples for Testing 4.

Means of total errors and also perseverative errors for each category and for each testing are plotted (figures 26a, b, c, d, e)

One-Way ANOVA
Table 53 Total errors on three completed categories
WCST - Testing 1 (N=9) 7 years

Source	S.S	df	M.S	F.ratio	Sig.Level
Treatment	136.96	2	68.48	3.66	.05
Subjects	78.52	8			
T x S	299.04	16	18.69		

One-Way ANOVA
Table 54 Total errors on three completed categories
WCST - Testing 2 (N=10) 7 years

Source	S.S	df	M.S	F.ratio	Sig.Level
Treatment	34.07	2	17.03	2.93	
Subjects	68.8	9			
T x S	104.6	18	5.81		

One-Way ANOVA
Table 55 Total errors on three completed categories
WCST - Testing 3 (N=15) 7 years

Source	S.S	df	M.S	F.ratio	Sig.Level
Treatment	164.58	2	82.29	3. 8	.05
Subjects	171.24	14			
T x S	606.76	28	21.67		

One-Way ANOVA
Table 56 Total errors on three completed categories
WCST - Testing 4 (N=15) 7 years

Source	S.S	df	M.S	F.ratio	Sig.Level
Treatment	172.98	2	86.49	6.83	.01
Subjects	92.58	14			
T x S	354.36	28	12.66		

One-Way ANOVA
Table 57 Total errors as three completed categories
WCST - Testing (N=13) 4 - 5 years

Source	S.S	df	M.S	F.ratio	Sig.Level
Treatment	298.05	2	149.03	9.55	.001
Subjects	96.77	12			
T x S	374.62	24	15.61		

From ANOVAs of total errors on sub-samples, who completed the first three categories on Wisconsin Card Sorting Test, and from plotting means of total errors, and also perseverative errors, for each testing, it would appear that total errors made increased with each successive reversal necessary to complete a category. Figures 26a, b, c, d, e show perseverative errors also increase, and it is of interest to the investigation to test the relationship of perseverative to total errors. Proportions of perseverative to total errors were derived, and arc-sine transformation made from the proportions to enable ANOVA to be carried out. For each testing, one way ANOVA for repeated measures were computed using statistical procedures for Apple (Versey 1983). The results are presented as

1) Means Table 58

and

2) ANOVA Tables 59, 60, 61, 62, 63

Table 58 Means of Proportions of Perseverative to Total errors first three categories achieved (arc-sine) (WCST)

	Category 1	Category 2	Category 3
7 yrs-Testing 1	19.8	55.86	48.87
Testing 2	7.16	57.27	48.08
Testing 3	20.5	61.66	59.1
Testing 4	7.96	53.43	53.98
5 yrs-Testing 4	6.16	64.89	53.86

Table 59 One Way ANOVA - Proportions of Perseverative to Total errors on first three categories achieved (Arc-sine) Testing 1, 7 years (WCST), (N=9)

Source	S.S	df	M.S	F.ratio	Sig.Level
Treatment	6582.18	2	3291.09	6.04	.05
Subjects	7088.39	8			
T x S	8715.58	16	544.72		

Table 60 One Way ANOVA - Proportions of Perseverative to Total errors on first three categories achieved (Arc-sine) Testing 2, 7 years (WCST) (N=10)

Source	S.S	df	M.S	F.ratio	Sig.Level
Treatment	14233.53	2	7116.76	22.97	.001
Subjects	4676.51	9			
T x S	5577.52	18	309.86		

Table 61 One Way ANOVA - Proportions of Perseverative to Total errors on first three categories achieved (Arc-sine) - Testing 3, 7 years (WCST) (N=15)

Source	S.S	df	M.S	F.ratio	Sig.Level
Treatment	15949.87	2	7974.93	15.52	.001
Subjects	12162.81	14			
T x S	14389.64	28	513.92		

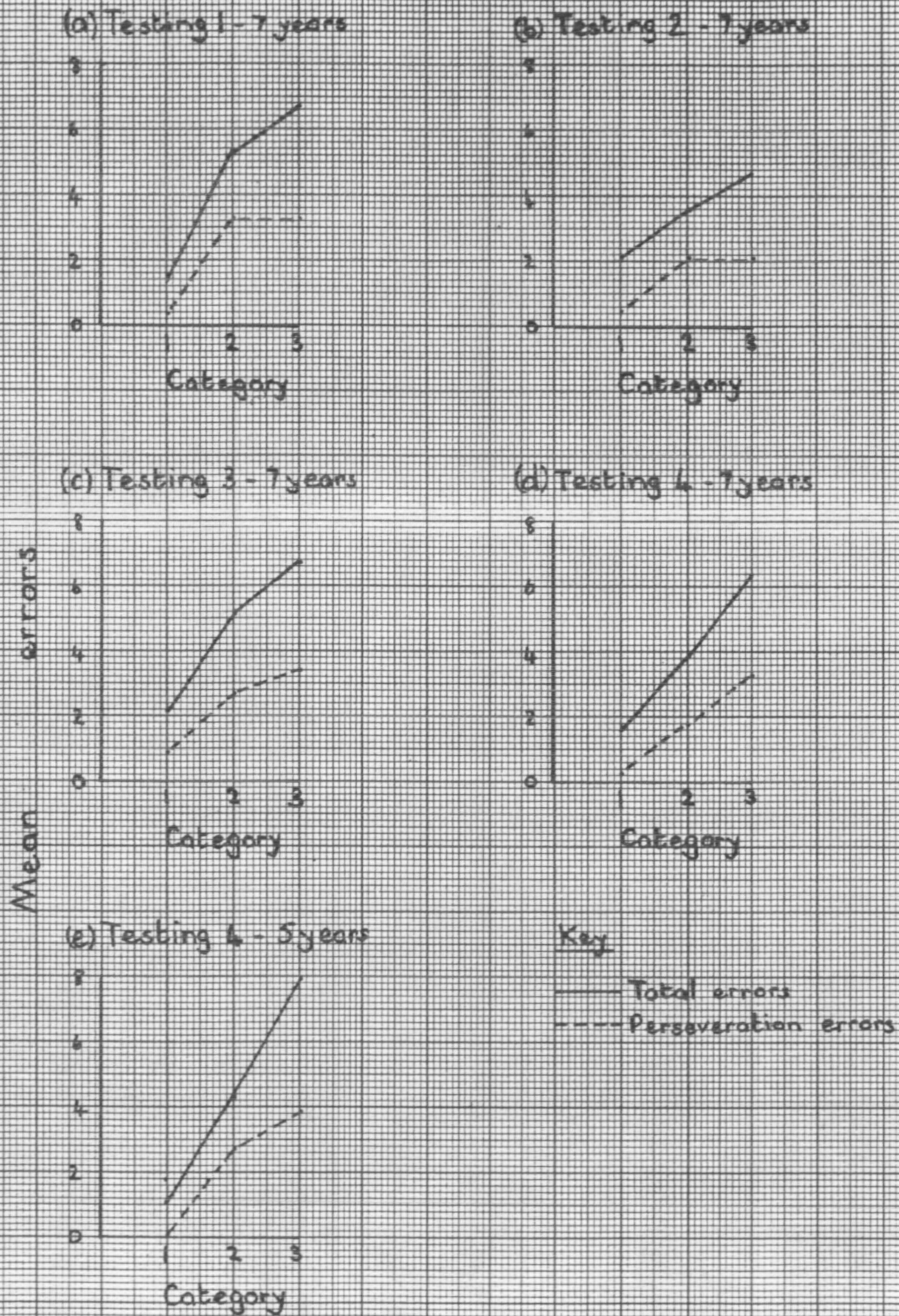
Table 62 One Way ANOVA - Proportion of Perseverative to Total errors on first three categories achieved (Arc-sine Testing 4, 7 years (WCST) (N=15)

Source	S.S	df	M.S	F.ratio	Sig.Level
Treatment	20924.28	2	10462.14	21.84	.001
Subjects	5088.04	14			
T x S	13414.4	28	479.09		

Table 63 One Way ANOVA - Proportion of Perseverative to Total errors on first three categories achieved (Arc-sine Testing 4, 5 years (WCST) (N=13)

Source	S.S	df	M.S	F.ratio	Sig.Level
Treatment	25321.1	2	12660.55	22.22	.001
Subjects	1896.23	12			
T x S	13676.44	24	569.85		

Fig 26 Wisconsin Card Sorting Test - Means of Total and Perseveration errors for 1st three categories by testing



Within Task Analysis of Two-Choice Discrimination Learning

As has been fully described in Chapter 3, two conditions (non reversal and reversal) of this were administered to each child at each of the four testing occasions in counter-balanced order. It was hypothesised that more errors would be made in the reversal than non-reversal to the initially preferred response, and tested in the null form.

Table 64 shows that significantly more errors were made on the first condition experienced by the children at the each age level. Overall of the 24 testing situations, 22 gave the first condition (reversal or non-reversal) as yielding more errors with the first testing for 3 year olds showing the same number of errors for each condition (Binomial .001). The Binomial Test was also applied to the individual testing situations by age, and results are given in the table below.

Table 64
Two-Choice Discrimination Learning - Reversal/Non-Reversal Conditions (including equal scores) - Binomial Test

Age	1st received Non-Reversal			1st received Reversal		
	N.R.	R	Binomial	N.R	R	Binomial
3 years - Testing 1	8	8			8	
2	10.5	2.5	.05	4.5	9.5	
3	9.5	2.5	.05	5.5	7.5	
4.	9	3		3.5	9.5	
5 years - Testing 1	14.5	2.5	.01	1	14	.001
2	11.5	3.5	.05	3	14	.01
3	10	7		3.5	11.5	.05
4	8.5	6.5		3.5	12.5	.05
7 years - Testing 1	15.5	1.5	.001	.05	14.5	.001
2	11	4		.05	16.5	.001
3	16	0	.001	2	12	.01
4	8.5	4.5		6	10	

Three Choice Discrimination Learning - Effects of Reinforcement Conditions on Error Behaviour

Analysis using t-tests for independent samples was made of errors at each age level at each testing and between reinforcement conditions. First, t-tests were carried out of perseveration errors made by the sub samples at each age level, which experienced either a 66% reinforcement condition or 33% reinforcement condition.

Results are presented as Table 65

Table 65 Mean Perseveration errors made on 66% and 33% Reinforcement Conditions

	Testing 1				Testing 2				Testing 3				Testing 4			
Age	$\bar{x}$66%	$\bar{x}$33%	t	p	$\bar{x}$66%	$\bar{x}$33%	t	p	$\bar{x}$66%	$\bar{x}$33%	t	p	$\bar{x}$66%	$\bar{x}$33%	t	p
3 years	32.38	34.81	.29		26.56	28.75	.28		4.69	14.69	2.01		4.19	8.25	2.15	.05
5 years	9.88	10.13	.05		2.88	3.06	.17		2.44	5.25	1.19		.88	4.63	3.16	.01
7 years	7.25	3.19	.9		.81	6.44	2.91	.01	1.69	2.06	.49		.75	1.81	1.95	

Secondly, t-tests for independent samples were carried out on total errors made on each reinforcement condition by the sub-samples at each age level and to each testing. Results are presented as Table 66

Table 66 Mean Total errors made on 66% and 33% Reinforcement Conditions

	Testing 1				Testing 2				Testing 3				Testing 4			
Age	$\bar{x}$66%	$\bar{x}$33%	t	p	$\bar{x}$66%	$\bar{x}$33%	t	p	$\bar{x}$66%	$\bar{x}$33%	t	p	$\bar{x}$66%	$\bar{x}$33%	t	p
3 years	51.75	55.94	0.58		42.38	52.63	1.33		27.06	35.63	1.35		26.0	40.38	2.83	.01
5 years	35.75	42.44	1.04		24.63	34.31	1.88		19.63	34.56	2.66	.05	15.19	30.38	3.07	.01
7 years	24.0	38.31	2.12	.05	17.06	36.44	3.69	.001	24.44	36.13	3.03	.01	15.25	29.38	3.23	.01

Product-Moment Correlations

Product-Moment correlation coefficients have been computed between perseveration scores on each test and pre-test scores for each age level and testing separately. This procedure was adopted in order to avoid spuriously high correlations which would have resulted from analysis of all subjects combined.

The resulting correlation matrices are presented on the following pages. As stated in Chapter 2, a significance level of $p < .05$ is accepted as sufficient to reject a null hypothesis of no significant correlation between scores from pre-tests and scores from each or any of the six experimental tasks. For the sub-sample size of 32 each of the three age levels $p < .05$, $r \geqslant 0.33$.

Abbreviations used in the matrices are as follows:

RCPM - Ravens Coloured Progressive Matrices - Raw Scores

Language Comprehension - Reynell Verbal Comprehension Sub-Scale-Standard Scores

M.F.F Latency - Matching Familiar Figures Latency Scores (in seconds)

M.F.F No. 1st Correct - Matching Familiar Figures - Number of First Time Correct Responses

WCST - Wisconsin Card Sorting Test

Sp. Alt - Spontaneous Alternation

Oddity - Oddity Problem

Two-Choice Discrim. - Two Choice Discrimination Learning Task

Three-Choice Discrim. - Three Choice Discrimination Learning Task

Attributes - Attributes Task

Table 67 Correlation co-efficients between Test Scores - Pre-tests and Experimental Tasks

Testing 1 - 3 year old group (N=32)

	RCPM	Language Comprehension	MFF Latency	MFF No 1st correct	WCST	Sp.Alt	Oddity	2 choice Discrim.	3 choice Discrim.	Attributes
RCPM		44	34	17	01	-59	14	-31	-35	-26
Language Comprehension			21	52	17	-69	-01	-19	-32	-27
MFF Latency				12	22	-13	16	-14	-01	-01
MFF 1st correct					02	-32	-06	-10	-19	-09
WCST						-03	02	08	-07	-63
Sp.Alt							01	31	51	48
Oddity								20	12	09
2 choice Discrim.									32	45
3 choice Discrim.										62

Table 68 Correlation co-efficients between Test Scores - Pre-tests and Experimental Tasks

Testing 2 - 3 year old group (N=32)

	RCPM	Language Comprehension	MFF Latency	MFF No 1st correct	WCST	Sp.Alt	Oddity	2 choice Discrim.	3 choice Discrim.	Attributes
RCPM		44	34	17	-11	-37	-07	01	-19	-19
Language Comprehension			21	52	-23	-38	-28	14	-32	-28
MFF Latency				12	18	-25	-06	-28	-15	-10
MFF 1st correct					-12	-47	-27	02	-25	-37
WCST						09	16	-14	-11	-15
Sp.Alt							29	24	57	58
Oddity								01	40	17
2 choice Discrim.									18	28
3 choice Discrim.										61

Table 69 Correlation co-efficients between Test Scores - Pre-tests and Experimental Tasks

Testing 3 - 3 year old group (N=32)

	RCPM	Language Comprehension	MFF Latency	MFF No 1st correct	WCST	Sp.Alt	Oddity	2 choice Discrim.	3 choice Discrim.	Attributes
RCPM		44	34	17	27	-09	-08	-29	-09	-26
Language Comprehension			21	52	-05	-06	-35	-24	-39	-26
MFF Latency				12	19	-03	-01	-05	-06	-08
MFF 1st correct					06	-28	-10	-46	-10	-15
WCST						-12	10	-19	30	-08
Sp.Alt							45	26	16	30
Oddity								-06	37	49
2 choice Discrim.									01	-11
3 choice Discrim.										46

Table 70 Correlation co-efficients between Test Scores - Pre-tests and Experimental Tasks

Testing 4 - 3 year old group (N.32)

	RCPM	Language Comprehension	MFF Latency	MFF No 1st correct	WCST	Sp.Alt	Oddity	2 choice Discrim.	3 choice Discrim.	Attributes
RCPM		44	34	17	-34	11	-10	01	-00	-20
Language Comprehension			21	52	-47	29	-15	21	-12	-43
MFF Latency				12	-18	-05	-24	22	02	-17
MFF 1st correct					-29	07	-11	15	-19	-34
WCST						-36	00	-40	-01	40
Sp.Alt							-03	10	-31	-28
Oddity								-21	-16	20
2 choice Discrim.									22	-15
3 choice Discrim.										13

Table 71 Correlation co-efficients between Test Scores - Pre-tests and Experimental Tasks

Testing 1 - 5 year old group (N-32)

	RCPM	Language Comprehension	MFF Latency	MFF No 1st correct	WCST	Sp.Alt	Oddity	2 choice Discrim.	3 choice Discrim.	Attributes
RCPM		26	53	45	36	30	-18	-17	-14	-20
Language Comprehension			-04	07	-01	-04	-32	09	-22	-22
MFF Latency				56	30	08	-07	-28	-18	-02
MFF 1st correct					32	35	-38	06	09	17
WCST						22	-17	-29	03	04
Sp.Alt							-10	-04	19	27
Oddity								04	32	07
2 choice Discrim.									-18	-01
3 choice Discrim.										34

Table 72 Correlation co-efficients between Test Scores - Pre-tests and Experimental Tasks

Testing 2 - 5 year old group (N=32)

	RCPM	Language Comprehension	MFF Latency	MFF No 1st correct	WCST	Sp.Alt	Oddity	2 choice Discrim.	3 choice Discrim.	Attributes
RCPM		26	53	45	-10	-06	-27	27	49	00
Language Comprehension			-04	07	-25	-25	-04	-22	09	15
MFF Latency				56	-06	-07	-17	08	47	-17
MFF 1st correct					-11	-10	-15	04	32	-19
WCST						26	-07	-24	-20	-26
Sp.Alt							04	06	-11	05
Oddity								-05	-18	-02
2 choice Discrim.									04	-16
3 choice Discrim.										-06

Table 73 Correlation co-efficients between Test Scores - Pre-tests and Experimental Tasks

Testing 3 - 5 year old group (N 32)

	RCPM	Language Comprehension	MFF Latency	MFF No 1st correct	WCST	Sp.Alt	Oddity	2 choice Discrim.	3 choice Discrim.	Attributes
RCPM		26	53	45	01	19	-29	-23	-08	45
Language Comprehension			-04	07	-02	16	04	00	10	-04
MFF Latency				56	-01	00	-29	00	-05	63
MFF 1st correct					-02	-07	-16	-22	08	4
WCST						-36	15	15	-11	02
Sp.Alt							01	09	12	04
Oddity								34	-05	-20
2 choice Discrim.									18	06
3 choice Discrim.										-10

Table 74 Correlation co-efficients between Test Scores- Pre-tests and Experimental Tasks

Testing 4 - 5 year old group (N=32)

	RCPM	Language Comprehension	MFF Latency	MFF No 1st correct	WCST	Sp.Alt	Oddity	2 choice Discrim.	3 choice Discrim.	Attributes
RCPM		26	53	45	-21	28	-22	07	27	26
Language Comprehension			-04	07	-04	01	-13	02	59	-09
MFF Latency				56	-20	26	-19	23	05	25
MFF 1st correct					-07	03	-11	17	13	13
WCST						-02	19	-02	-08	-09
Sp.Alt							-27	-11	02	-01
Oddity								-04	-14	-22
2 choice Discrim.									25	-05
3 choice Discrim.										18

Table 75 Correlation co-efficients between Test Scores- Pre-tests and Experimental Tasks

Testing 1 - 7 year old group (N=32)

	RCPM	Language Comprehension	MFF Latency	MFF No 1st correct	WCST	Sp.Alt	Oddity	2 choice Discrim.	3 choice Discrim.	Attributes
RCPM		34	55	53	-34	21	-27	-03	-09	-01
Language Comprehension			-05	15	11	12	-34	24	14	-31
MFF Latency				61	-10	00	02	-09	01	08
MFF 1st correct					-19	28	06	11	27	07
WCST						-06	09	36	-06	-17
Sp.Alt							-04	-07	25	-16
Oddity								-11	06	39
2 choice Discrim.									10	-11
3 choice Discrim.										-06

Table 76 — Correlation co-efficients between Test Scores- Pre-tests and Experimental Tasks

Testing 2 - 7 year old group (N=32)

	RCPM	Language Comprehension	MFF Latency	MFF No 1st correct	WCST	Sp.Alt	Oddity	2 choice Discrim.	3 choice Discrim.	Attributes
RCPM		34	55	53	-19	40	-08	02	-23	-04
Language Comprehension			-05	15	-24	10	-15	-05	01	-07
MFF Latency				61	-15	11	11	08	-19	-05
MFF 1st correct					-17	30	09	02	-24	18
WCST						-18	35	-26	24	21
Sp.Alt							-29	11	-25	21
Oddity								-21	-07	65
2 choice Discrim.									10	-17
3 choice Discrim.										-06

Table 77 Correlation co-efficients between Test Scores - Pre-tests and Experimental Tasks

Testing 3 - 7 year old group (N 32)

	RCPM	Language Comprehension	MFF Latency	MFF No 1st correct	WCST	Sp.Alt	Oddity	2 choice Discrim.	3 choice Discrim.	Attributes
RCPM		34	55	53	13	27	-26	17	-11	09
Language Comprehension			-05	15	-07	13	-08	-46	22	-01
MFF Latency				61	40	-09	-25	-16	-30	15
MFF 1st correct					10	06	-31	-20	-04	34
WCST						-26	25	-05	09	06
Sp.Alt							-24	-03	30	-33
Oddity								-08	11	11
2 choice Discrim.									21	01
3 choice Discrim.										-10

Table 78 Correlation co-efficients between Test Scores - Pre-tests and Experimental Tasks

Testing 4 - 7 year old group (N=32)

	RCPM	Language Comprehension	MFF Latency	MFF No 1st correct	WCST	Sp.Alt	Oddity	2 choice Discrim.	3 choice Discrim.	Attributes
RCPM		34	55	53	-13	11	-19	-19	-03	-01
Language Comprehension			-05	15	-02	14	-10	-05	02	13
MFF Latency				61	-33	06	-19	-26	-09	-09
MFF 1st correct					-36	17	-24	-15	06	05
WCST						-30	06	12	-15	24
Sp.Alt							-39	18	15	05
Oddity								-07	00	-03
2 choice Discrim.									12	12
3 choice Discrim.										-14

Individual Curves

The statistical techniques for analysis which have been employed, depend upon averaging data for groups. Whilst they are useful for identification of main effects, particularly that of the age factor, individual variation is subsumed within the error term. Inspection of the mean square for error obtained from the ANOVAs indicates that considerable individual differences are present.

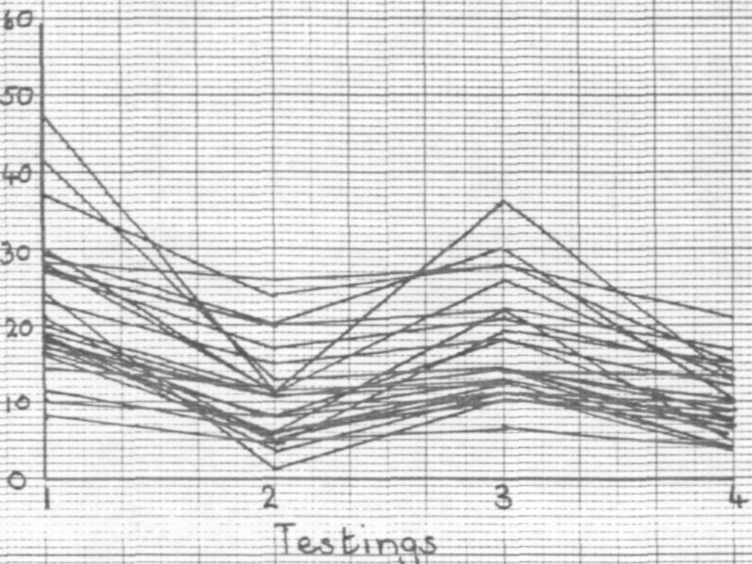
As a means of comparison of scores within testings for individuals, to enable inspection of data for sex and S.E.S. effects, and also to 'go beyond age-group comparison' (Wohlwill 1973), individual curves have been drawn for each subject separately across the four testings of raw perseveration errors made on Wisconsin Card Sorting Test and perseverations on Spontaneous Alternation.

Individual graphs are identifiable by subject number, sex (B or G) and S.E.S. (U=USES, L=LSES) and thus enable comparisons to be made between any of the possible combinations of age, sex, S.E.S. and task. The graphs have been transferred to microfiche, and are included as Appendix 8. From the individual graphs, groups of curves have been plotted; six from Wisconsin Card Sorting Test, and eight from Spontaneous Alternation, and are presented as Figures 27a, b, c, d, e, f (WCST , and Figures 28a, b, c, d, e, f, g, h (Spontaneous Alternation).

Samples of individual curves are included as Figures 29a, b, c, - WCST, and Figures 30a, b, c - Spontaneous Alternation.

Fig 27 Wisconsin Card Sorting Test
Individual Curve Fitting

(a) Curve type 1

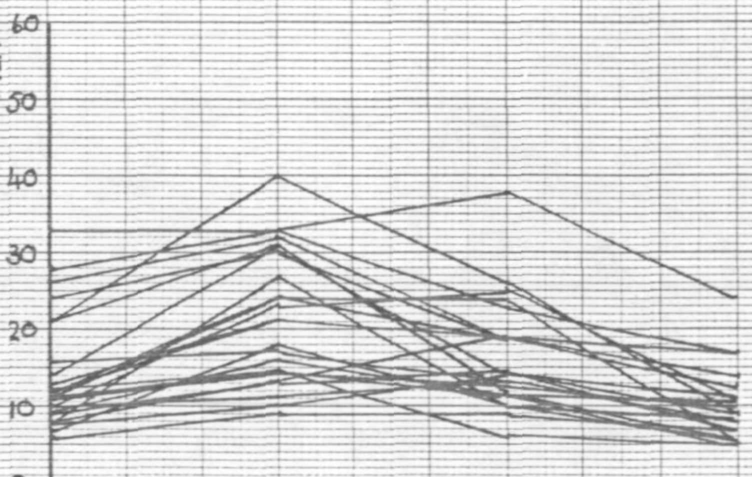


Subjects in group

3yrs	5yrs	7yrs
1 BL	35 BL	66 BL
10 GL	36 BL	67 BL
25 GU	39 BL	69 BL
26 GU	43 GL	72 BL
27 GU	45 GL	73 GL
30 GU	46 GL	74 GL
31 GU	47 GL	87 BU
	50 BU	88 BU
	51 BU	89 GU
	53 BU	93 GU
	54 BU	
	55 BU	
N = 7	N = 12	N = 10

Raw Perseveration errors

(b) Curve type 2

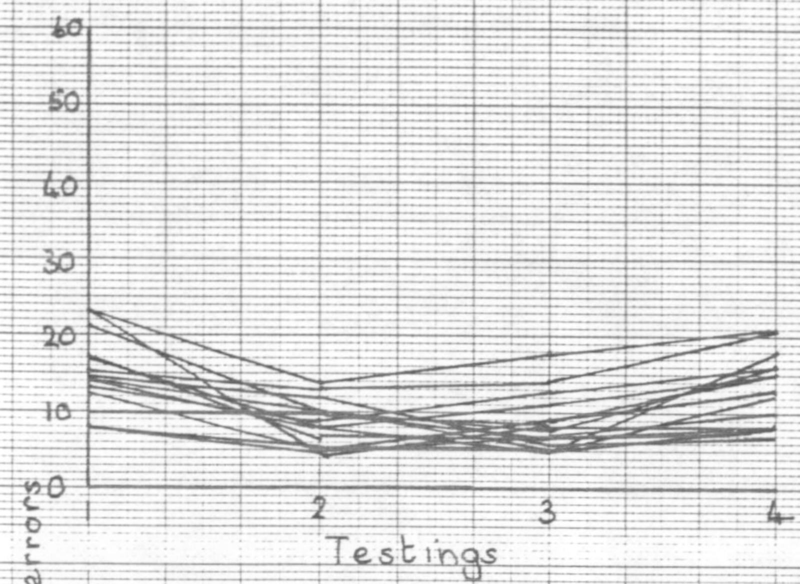


Subjects in group

3yrs	5yrs	7yrs
2 BL	33 BL	79 GL
5 BL	37 BL	80 GL
9 GL	40 BL	81 BU
11 GL	44 GL	92 GU
12 GL	49 BU	94 GU
14 GL	57 GU	95 GU
16 GL	59 GU	
19 BU	60 GU	
20 BU		
28 GU		
N = 10	N = 8	N = 6

Wisconsin Card Sorting Test
Individual Curve Fitting

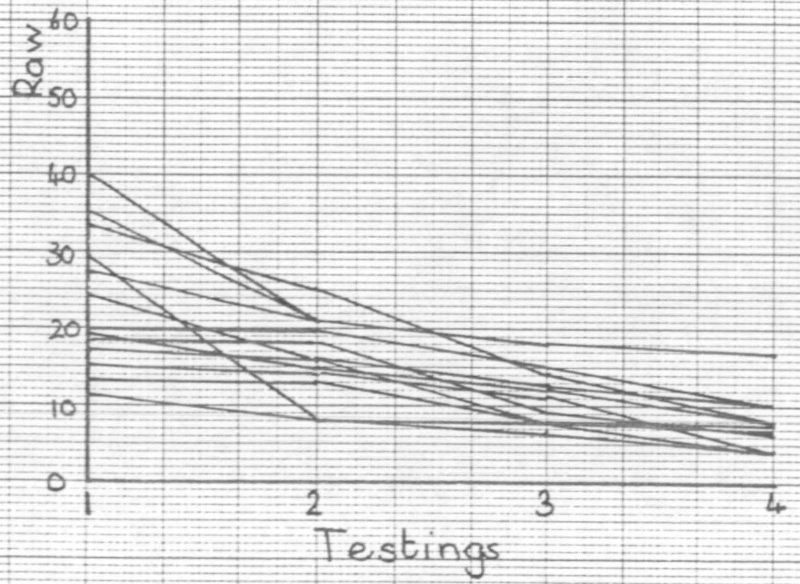
(c) Curve type 3



Subjects in group

3yrs	5yrs	7yrs
8 BL	48 GL	71 BL
24 BU	52 BU	75 GL
	56 BU	76 GL
	62 GU	78 GL
	63 GU	82 BU
		84 BU
		85 BU
		86 BU
		90 GU
N = 2	N = 5	N : 9

(d) Curve type 4

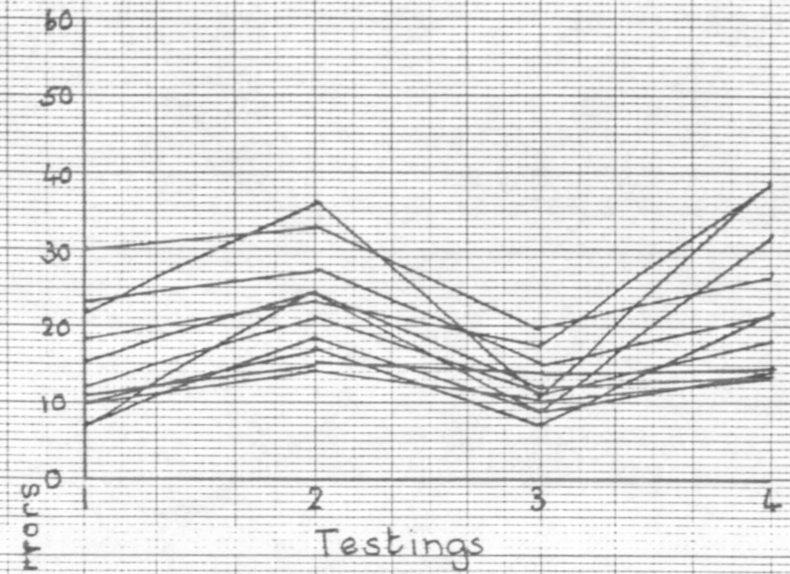


Subjects in group

3yrs	5yrs	7yrs
15 GL	34 BL	68 BL
17 BU	38 BL	83 BU
21 BU	58 GU	91 GU
22 BU	61 GU	96 GU
23 BU		
29 GU		
N = 6	N = 4	N = 4

Wisconsin Card Sorting Test
Individual Curve Fitting

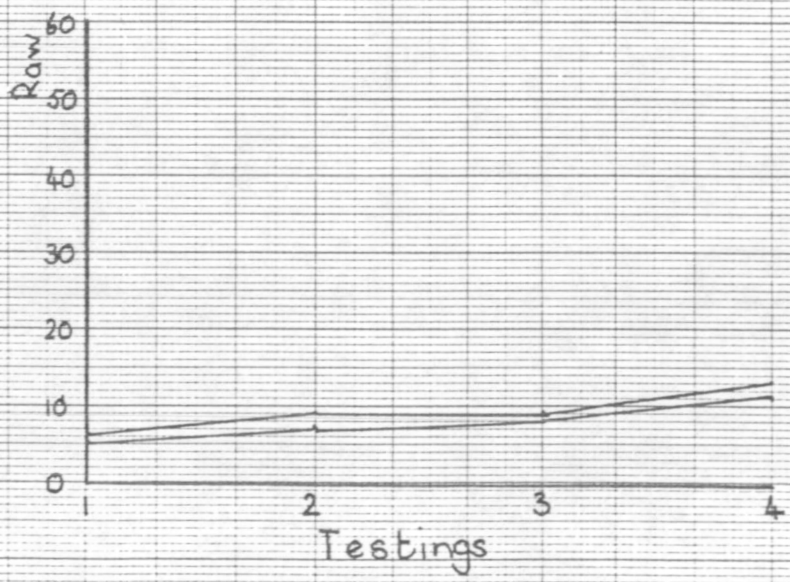
(e) Curve type 5



Subjects in group

3yrs	5yrs	7yrs
3 BL	42GL	65 BL
4 BL	66 GU	77GL
6 BL		
7 BL		
13GL		
18 BU		
32GU		
N=7	N=2	N=2

(f) Curve type 6

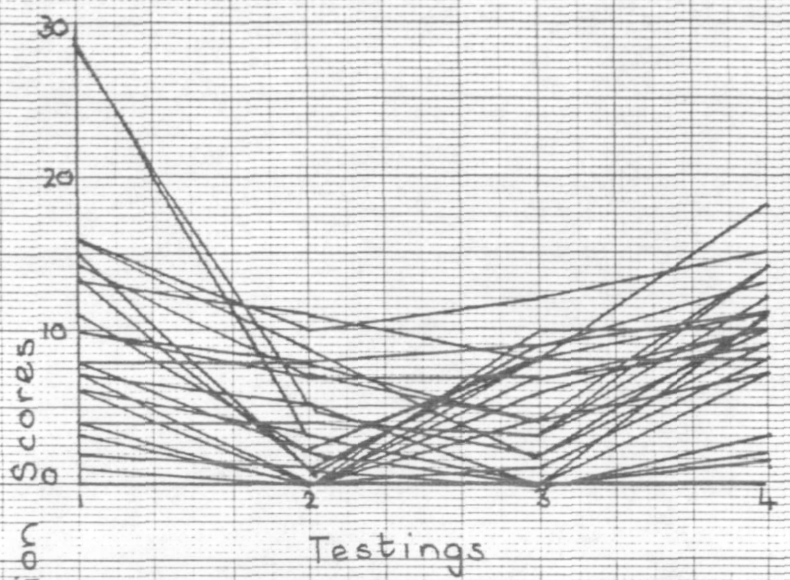


Subjects in group

3yrs	5yrs	7yrs
	41 GL	70 BL
N=0	N=1	N=1

Fig 28 Spontaneous Alternation Individual Curve Fitting

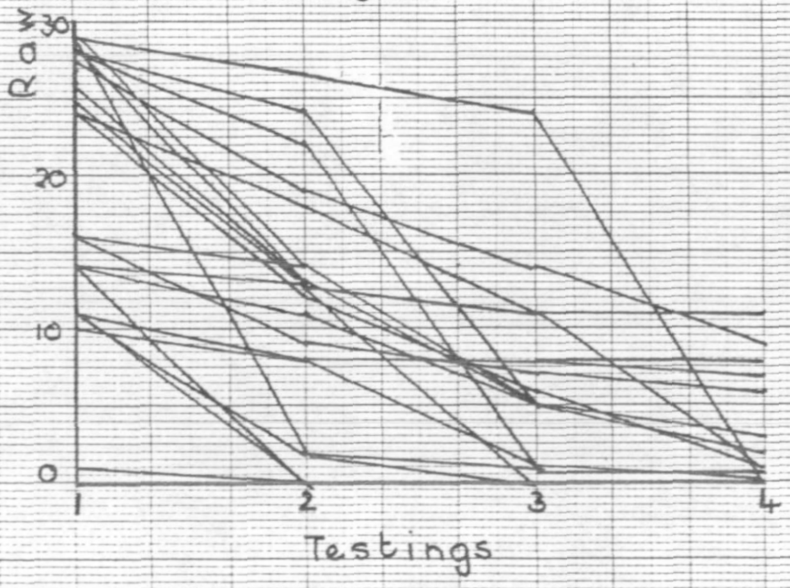
(a) Curve type 1



Subjects in group

3 yrs	5 yrs	7 yrs
1 BL	34 BL	66 BL
8 BL	36 BL	69 BL
24 BU	38 BL	73 GL
26 GU	39 BL	77 GL
27 GU	41 GL	78 GL
30 GU	42 BL	80 GL
	43 GU	83 BU
	46 GL	87 BU
	58 GU	88 BU
	60 GU	89 GU
	63 GU	90 GU
N = 6	N = 11	N = 11

(b) Curve type 2

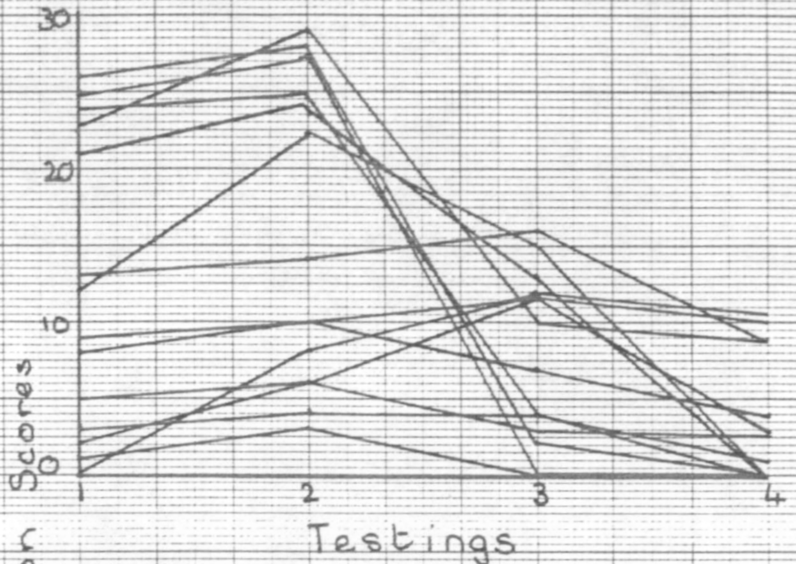


Subjects in group

3 yrs	5 yrs	7 yrs
2 BL	35 BL	65 BL
3 BL	37 BL	76 GL
5 BL	47 GL	79 GL
7 BL	54 BU	91 GU
9 GL		94 GU
10 GL		
13 GL		
15 GL		
16 GL		
17 BU		
20 BU		
22 BU		
23 BU		
31 GU		
32 GU		
N = 15	N = 4	N = 5

Spontaneous Alternation
Individual Curve Fitting

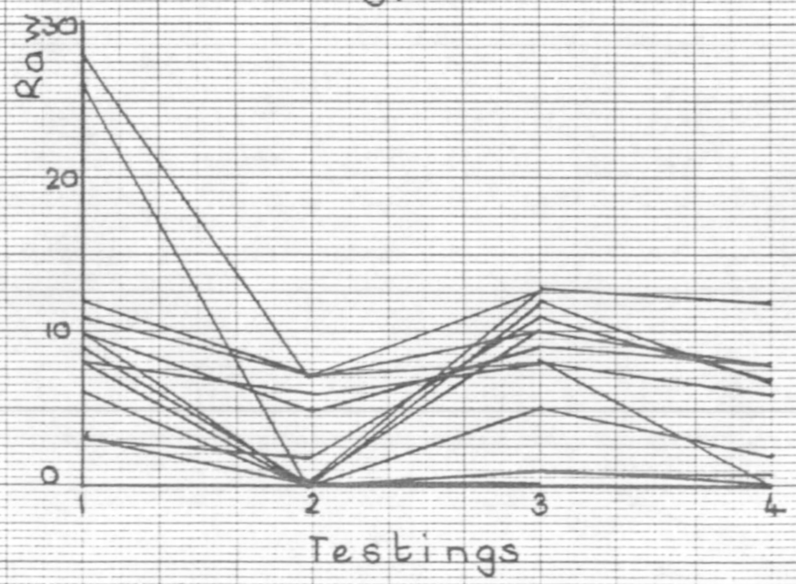
(c) Curve type 3



Subjects in group

3yrs	5yrs	7yrs
4 BL	40 BL	71 BL
6 BL	44 GL	72 BL
18 BU	48 GL	81 BU
25 BU	49 BU	
28 GU	56 BU	
	57 GU	
N=5	N=6	N=3

(d) Curve type 4

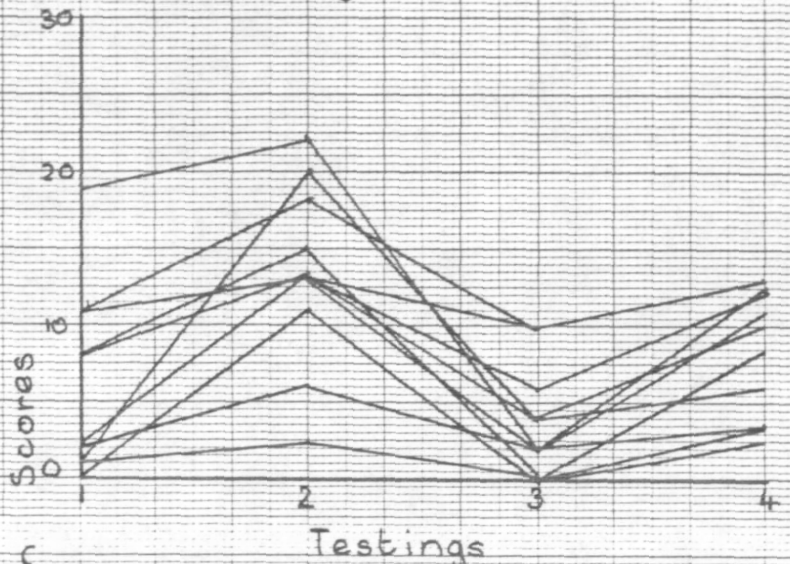


Subjects in group

3yrs	5yrs	7yrs
11 GL	50 BU	74 GL
12 GL	55 BU	75 GL
14 GL	59 GU	84 BU
	61 GU	86 BU
	64 GU	96 GU
N=3	N=5	N=5

Spontaneous Alternation
Individual Curve Fitting

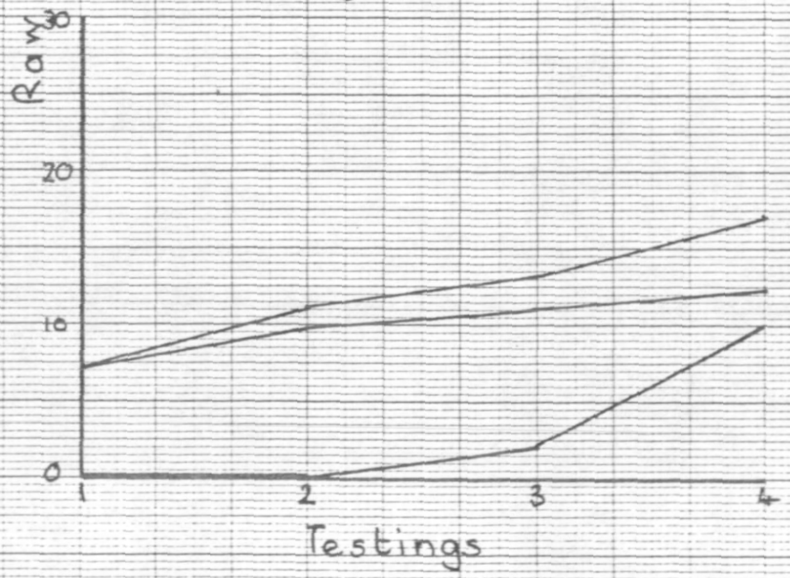
(e) Curve type 5



Subjects in group

3yrs	5yrs	7yrs
21 BU	33 BL	68 BL
29 GU	45 GL	82 BU
	52 BU	93 GU
	53 BU	95 GU
	62 GU	
N = 2	N = 5	N = 4

(f) Curve type 6



Subjects in group

3yrs	5yrs	7yrs
	51 BU	70 BL
		92 GU
N = 0	N = 1	N = 2

Spontaneous Alternation

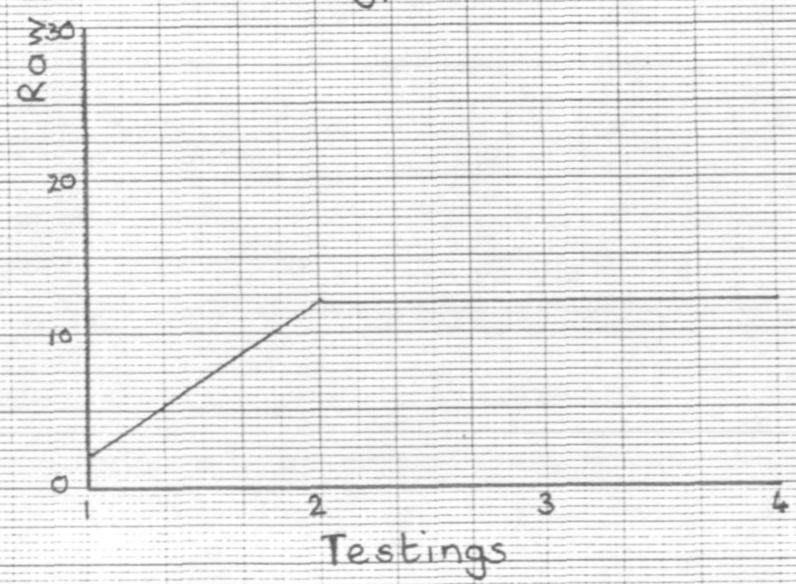
Individual Curve Fitting

(g) Curve type 7

Subjects in group

3yrs	5yrs	7yrs
19 BU		85 BW
N=1	N=0	N=1

(h) Curve type 8



Subjects in group

3yrs	5yrs	7yrs
		67BL
N=0	N=0	N=1

Fig 29a Individual curves. Wisconsin Card Sorting Test

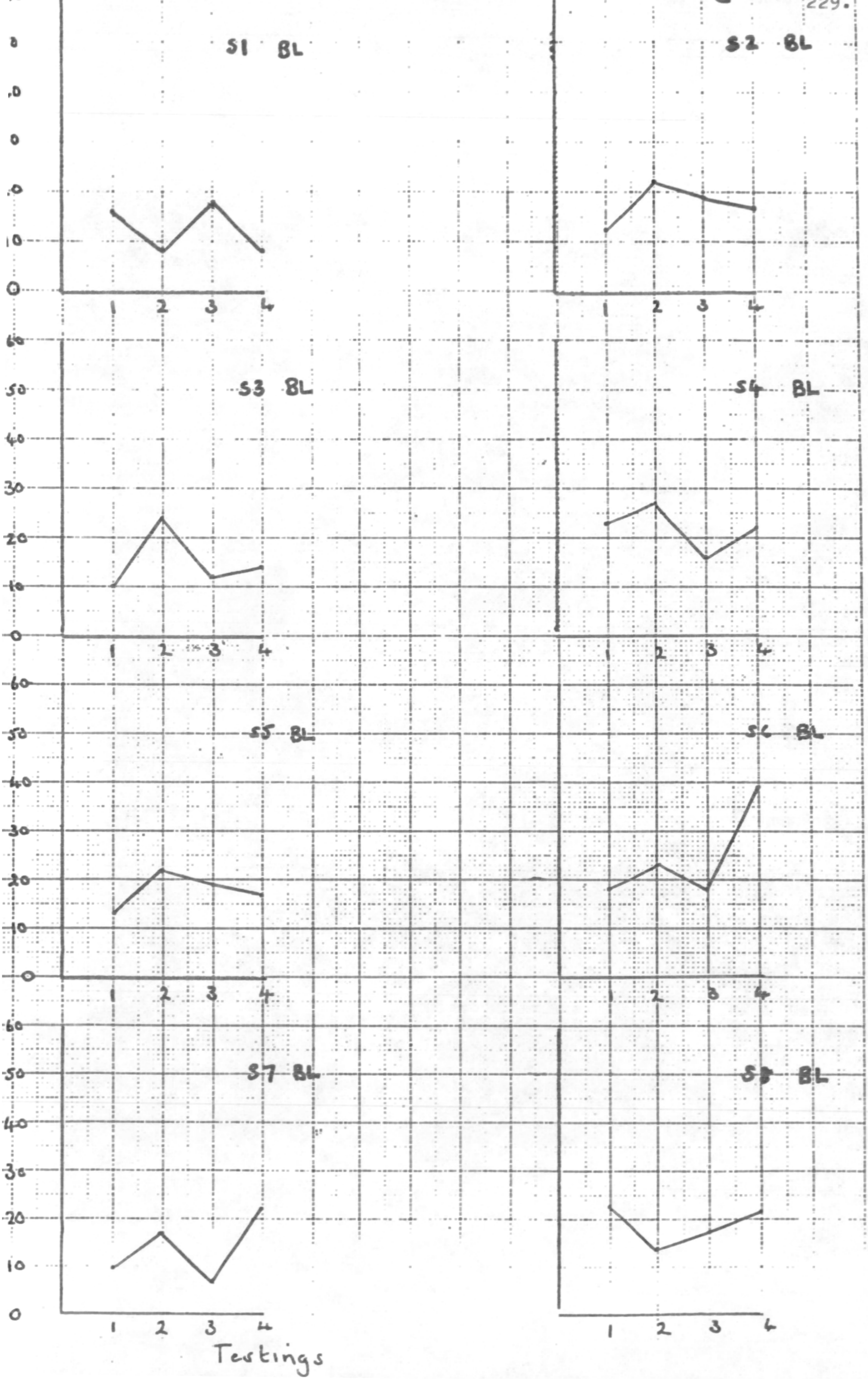


Fig 29b
Individual curves - Wisconsin Card Sorting Test

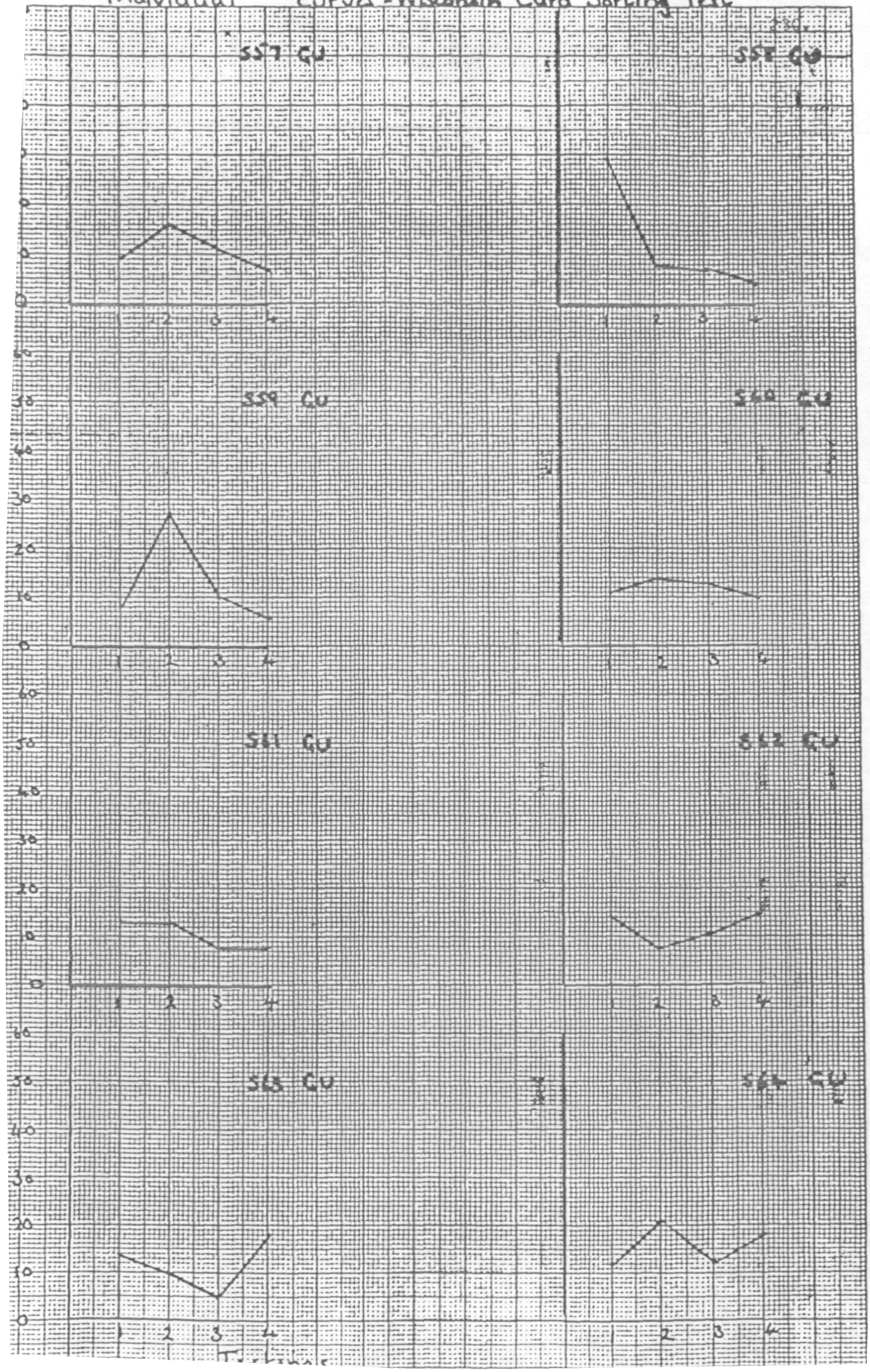


Fig 29c
Individual curves - Wisconsin Card Sorting Test

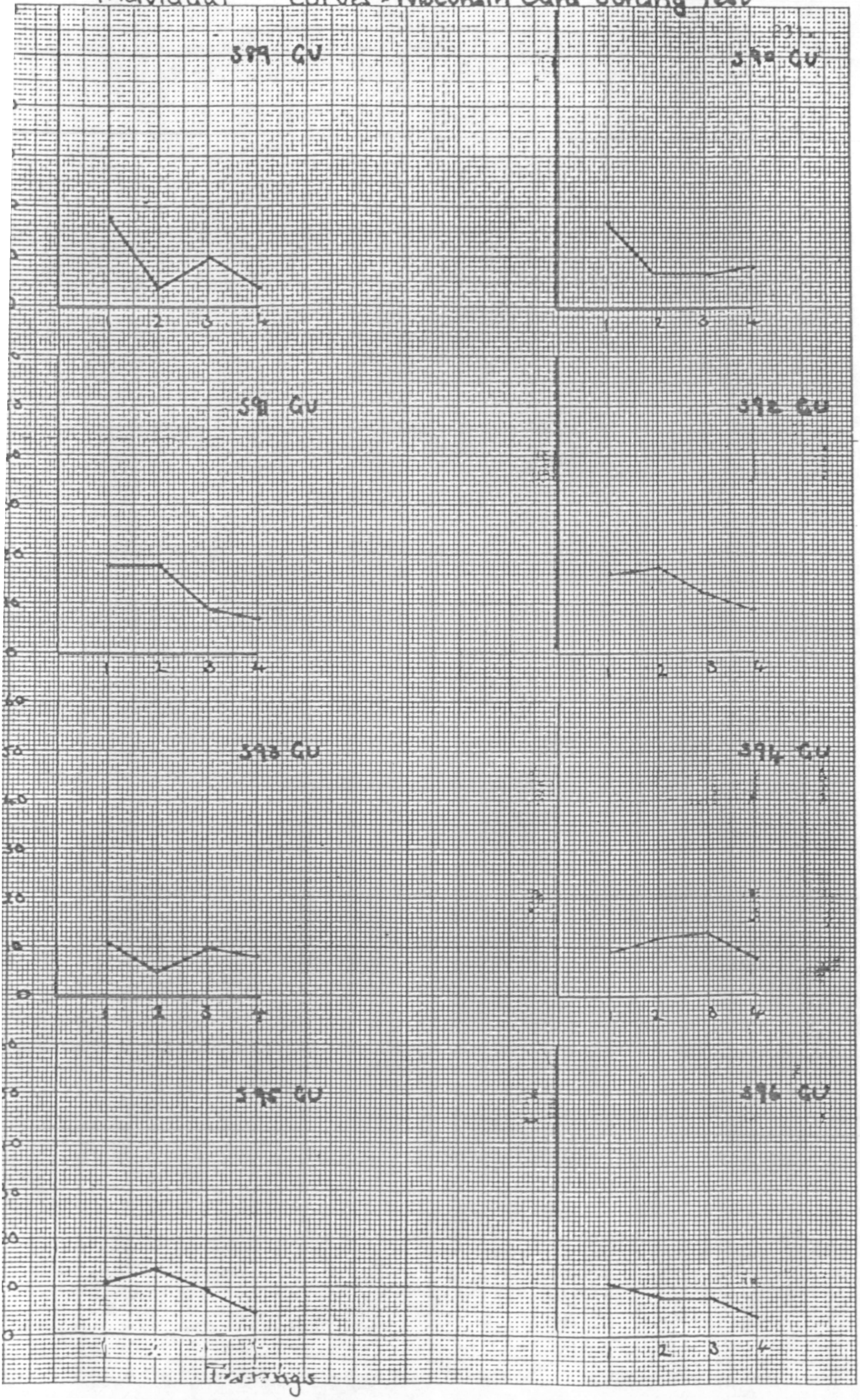
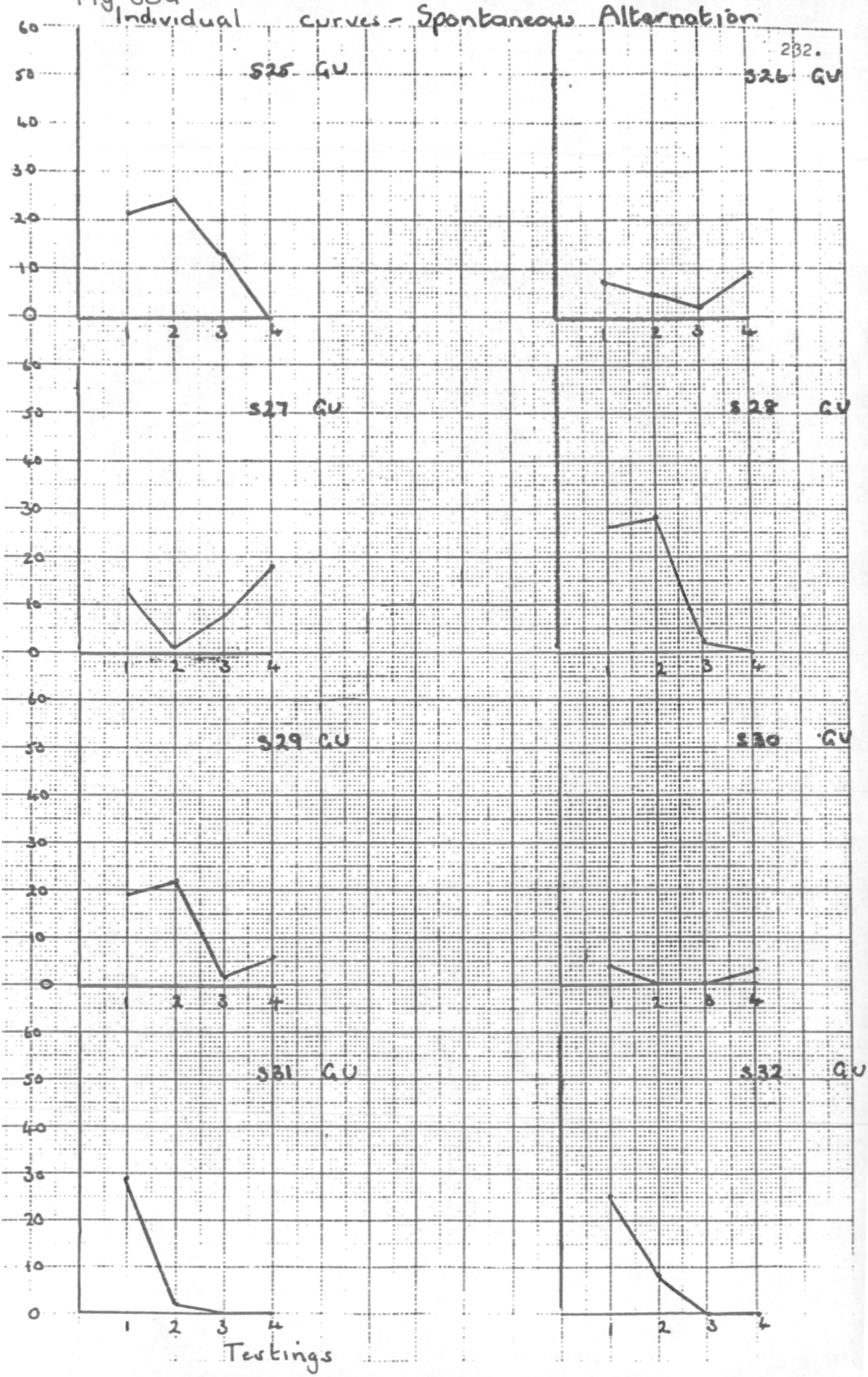


Fig 30a



Individual curves - Spontaneous Alternation
S25 GU
S26 GU
S27 GU
S28 GU
S29 GU
S30 GU
S31 GU
S32 GU
60
50
40
30
20
10
0
1
2
3
4
Testings

Fig 30b Individual curves - Spontaneous Alternation

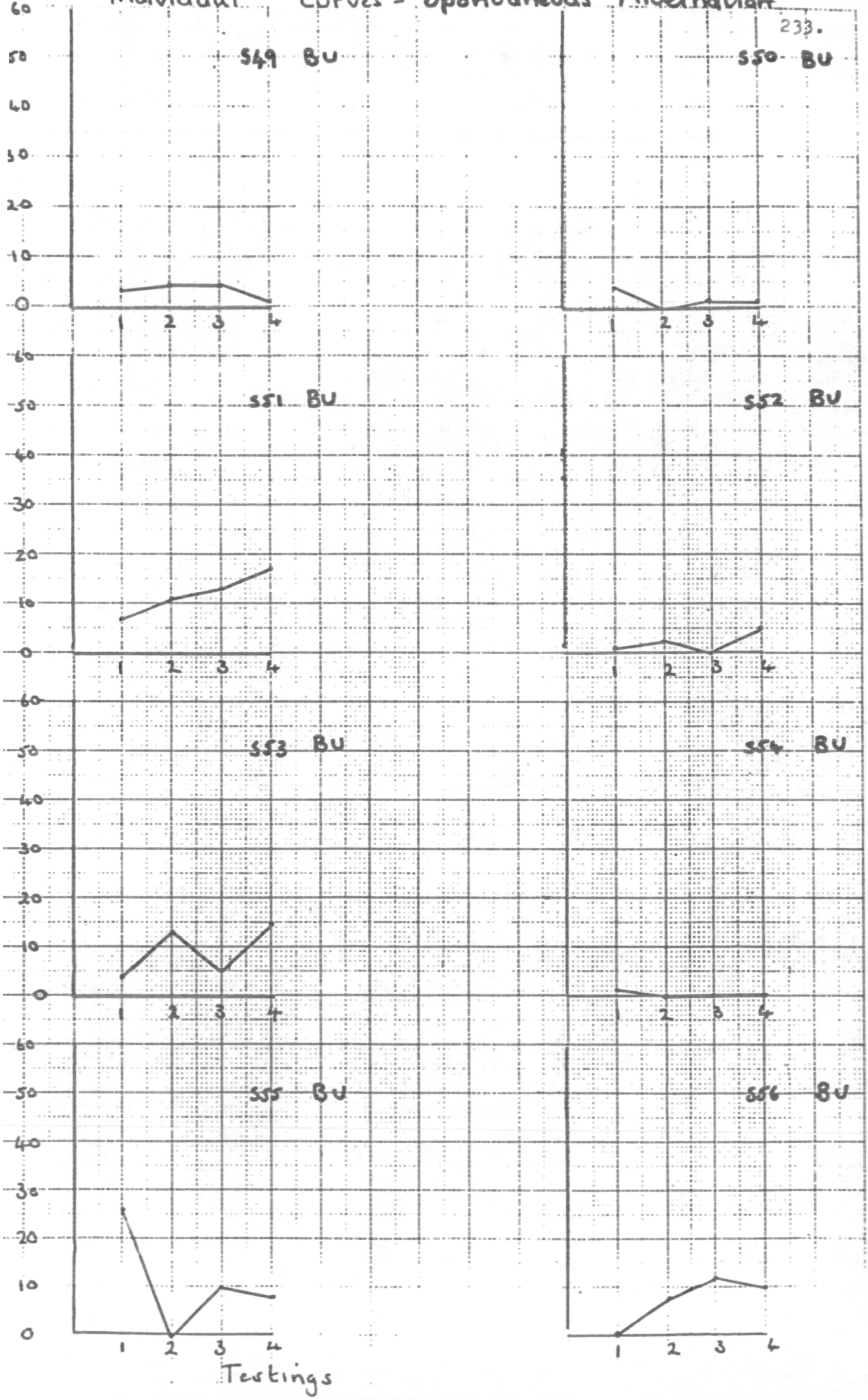
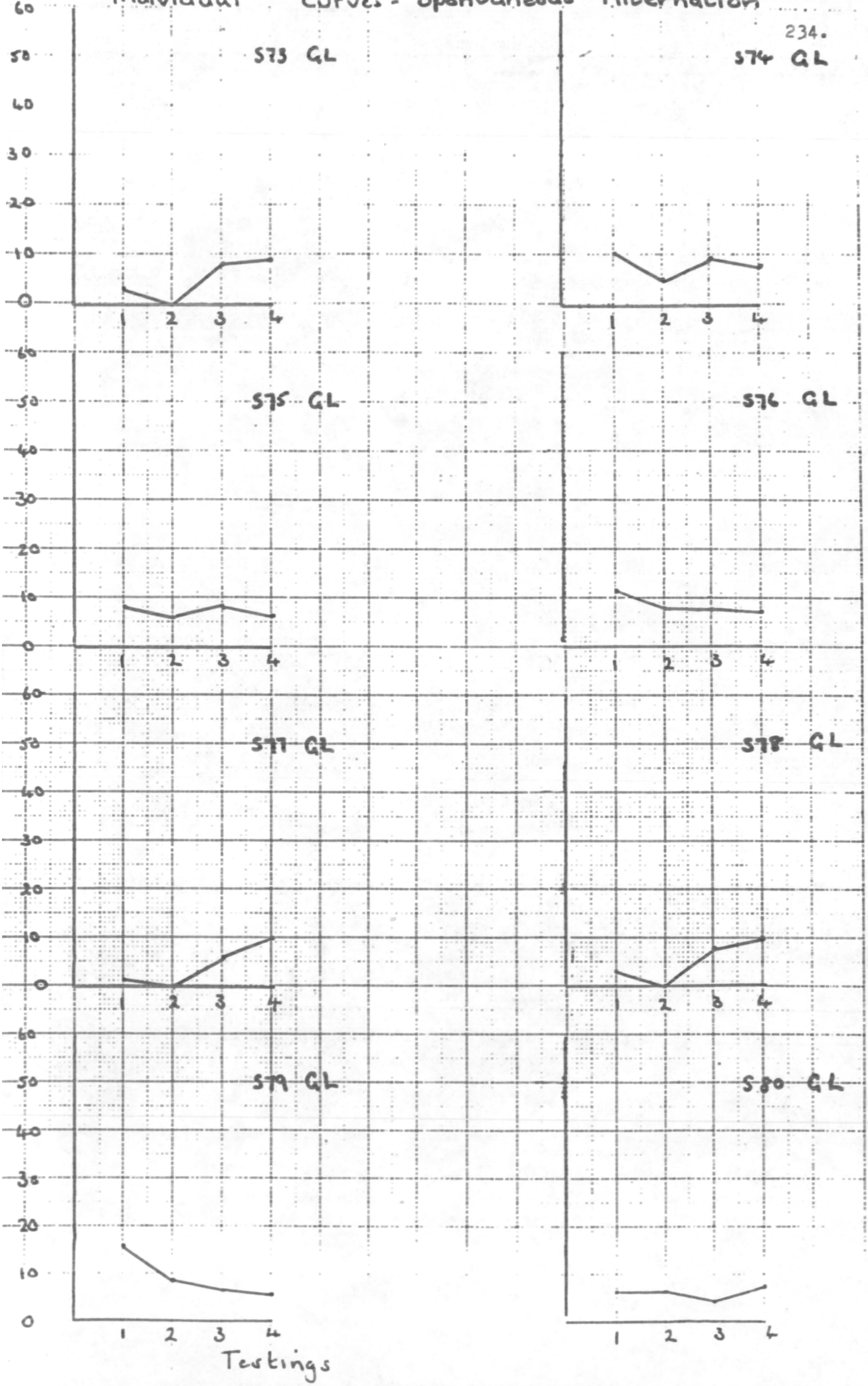


Fig 30c
Individual curves - Spontaneous Alternation



CHAPTER 5

Discussion

Introduction

The review of the literature has indicated that perseveration is the commonly used strategy in a variety of discrimination learning and probabilistic tasks by children aged four or less years. Perseveration, as an inert stereotyped and rigid form of behaviour, thus appears to have limited utility for solving problems, which demand the use of cues and errors in the formulation and testing ofalternative hypotheses. By contrast, the continuation of search for solution has been termed by Lunzer (1978) 'acceptance of lack of closure' (ALC), which he has argued to be a cognitive competence, parallel to the Piagetian meta-theory of intelligence as development of logical operations. It is suggested that the ability to form plans for problem-solving underlies ALC behaviour. Perseveration, from its definition as repetition of an ongoing response, is neither flexible nor logical,whereas both of these would characterise mature problem solving abilities. The response, which appears, from the literature reviewed for this research, to replace perseveration, and to become dominant from about four years of age, is alternation. Literally, it is a switching from one possible choice or response to another, and has been demonstrated across the same range of tasks as perseveration (eg. Schusterman 1963, Manley and Miller 1968, Miller, Dee-Wong, Moffatt and Manley 1969, Reiber 1966, Frith 1970a and 1970b). Like perseveration, an alternation strategy has been considered to be a stereotyped response (Levine 1966 , but since the response is to more than one choice, it appears less inert than its predecessor. The literature, too, has suggested that, subsequently, more complex patterns of alternation may be found (Gellerman 1931, Douglas 1975, 1976, Goulet and G dwin 1970 . However, as was stated in Chapter 2, the studies reviewed have been alm st entirely cr ss-secti nal in design, and therefore limited in their ability to illuminate the nature of changes within, as well as between, children during chronological age development. The aims of the present study, stated in Chapter 2, are to describe behavioural change in strategy availability and use, across a battery of experimental tasks, and to attempt explanation of some basic processes using a longitudinal study. The null hypotheses formulated have been tested by a variety of statistical procedures.

Age as a factor in strategy development

The developmental studies reviewed for this research have, through the use of cross-sectional designs, compared groups of children, using age as an independent variable. This approach is subject to criticism (Wohlwill 1973, Baltes and Nesselroade 1979), in that, if different age groups are compared, they are likely to differ significantly in performance on the variable tested. Comparison of groups by statistical techniques, such as ANOVA, use averaging procedures, and the significant results, which may then ensue, are taken as a justification of the technique employed. A view of developmental differences as age-related, thus becomes reinforced.

Nevertheless, age-related developmental differences may be very real. It is argued in the present study that the change from a dominant tendency to perseverate to one of alternation, and subsequent elaboration of strategies is a function of age, and with age, the development of planning behaviour.

The criticism made in Chapter 1 of research which has an underlying assumption of quantitative differences between ages, and which therefore compared young children through age levels with the frequently used undergraduate population is pertinent here (eg. Levine 1966, Weir 1964).

From the Principal Components Factor Analysis carried out as a preliminary analysis, it would appear that age is closely related to the number of perseveration errors and scores on the six experimental tasks administered to each child, on four separate test occasions of equal intervals, over two years. The null hypotheses (13,14) are rejected. Table 4, page 148, shows that age loads heavily on Factor 1, the only significant factor (Eigenvalue 2.66), with a communality of 0.81. Figure 6, shows from the Varimax (orthogonal) rotation, that age is in bipolar relationship to perseverations on all the experimental tasks. The results of Factor Analysis of age and experimental task seem, for Testing 2, to give a similar picture. At Testing 2, Factor 1 (Eigenvalue 2.89) accounts for 82.2% of variance, and in which age has a high negative loading. Like Testing 1, Varimax rotation of analysis of results shows age to be in the diagonally opposite quadrant to all experimental tasks (Figure 7).

For Testing 3, Age is again highly negatively loaded on Factor 1 which has an Eigenvalue of 2.16, (Table 8). However, unlike results from testings 1 and 2, when all experimental variables were negatively correlated with age (Tables 3 and 5), the correlation matrix shows a positive significant correlation of Age with Spontaneous Alternation, with all other variables remaining negatively, but significantly, correlated. Varimax rotation shows (Figure 8) some changes in location in quadrants of experimental task variables, but with age remaining alone.

However, from the results from Testing 4, not only does the correlation matrix (Table 9) show a highly significant positive correlation of Age with Spontaneous Alternation (r=.5),but interestingly, Varimax rotation places Spontaneous Alternation in the same quadrant with Age. Also of interest is the location of other experimental task variables. An inspection of Figure 9, giving the Varimax rotation, shows that '5' - the 2-Choice Discrimination Learning Task - has rotated anti-clockwise into a separate quadrant, and that '6' - 3-Choice Discrimination Learning Task has separated from '2' - the Wisconsin Card Sorting Test, '4' - Oddity Problem, and '7' - the Attributes Task. From Table 10, which shows the loading of each task on Factor 1, (Eigenvalue 2.11), it can be seen that the 2-Choice Discrimination Learning Task makes no contribution to the factor. Since this is the task on which children at all ages make the least errors, and thus is likely to make the least cognitive demand in utilisation of cues and errors, it is suggested that the locations of task variables at testing 4 is indicative of such demand. Further evidence for this inference, is given by the location of '3' - Spontaneous Alternation in the same quadrant as '1' - Age, as this task is defined by the child's own ability to impose, rather than to extract, structure. From this, it is suggested that Factor 1 may be considered to represent an emergent planning ability, which is substantially age, but also task, related.

Planning ability and the active reduction of error

A factor which he labelled as a planning factor, (Factor 3), was identified by Hofstaetter (1954) in his analysis of California Growth Study data, and the diagram illustrating this is given as Figure 1 on page61 of this study. However, Hofstaetter's work was not concerned with variation in task demand, nor with differential performance attributable to the degree of pattern inherent in specific tasks. This is considered to provide cues to the child for the extraction of the pattern, and hence active reduction of error.

The present study, by contrast, has used a variety of tasks. From the literature reviewed, the tasks illuminate the strategies used by children, whether these are consistent between tasks and across testings, and, thus, whether age-related developmental changes take place in the ability to utilise cues provided by experimental tasks, or problems. This is suggested as a process of active error reduction. The investigation of inter-individual differences, and intra-individual change across occasions, are argued by Buss (1979) to be a rationale for the use of a longitudinal study, such as the present one.

Practice effects in repeated measures designs

Chapter 4,page160, stated that change within individuals, ie.the reduction of perseveration, may be a function of practice with the task from its repeated administration. Accordingly, t-tests between the ages of overlap were carried out for each experimental task. Table 18 shows that the comparisons made between the 3 year old sub-group, who, by the fourth testing, had ended their fifth year, and the 5 year old sub-group, on their first testing, show significant results for Spontaneous Alternation ($t=3.37$, df 62, $p < .05$) and the Attributes Task ($t=2.16$, $p < .05$).

Means for three further tasks were higher for 5 year olds at Testing 1 than for the more task experienced group of 3 year olds, Testing 4. Similarly, results (Table 19) from t-test of each task for the overlapping samples of the 5 year old sub-group, who had completed their seventh year by Testing 4, and the 7 year old sub-group on Testing 1, showed significant t-values for the Wisconsin Card Sorting Test ($t=2.11$, df 62, $p < .05$), for the Two-Choice Discrimination Learning Task ($t=2.28$, df 62, $p < .05$) and for the Attributes Task ($t= 3.08$, df 62, $p < .05$).

For this cross-sectional comparison, means of all tasks were higher at seven years on Testing 1, indicating consistency of direction, even where not statistically significant.

It appears from these results that familiarity facilitates task performance in reducing perseveration, and this finding is consistent with the literature, eg. Donaldson (1978), Gibson and Rader (1979), and Bennett et al 1984). The possible contribution of practice effects which are more pronounced at the 7 year old level than at 5 years, and therefore indicative of age-related ability to utilise cues and errors, is referred to further in discussion of results from Analysis of Variance and other analyses for the implications for the research.

Difference between and within children on the experimental tasks

The null-hypotheses generated from a review of the literature, and stated in Chapter 2, have been tested by Four-way Analysis of Variance for each task using perseveration errors or scores as the dependent variable, and separately, using proportions of perseveration errors or scores to total errors, or trials. This procedure is considered appropriate, by virtue of the hypotheses under test, and from Factor Analysis, which identified age as a principal component in numbers of perseverations. It is also thought to justify the use in ANOVA of age as an independent variable, together with sex and socio-economic status.

Results from ANOVA for each task are considered separately.

Wisconsin Card Sorting Test

Table 20 shows Age to be a highly significant main effect between the three levels of this grouping factor. ($F=57.49$, df 2.84, $p < .001$). From the significant F ratio for Testings ($F=14.87$, df 3,252 $p < .001$), analysis for Trend yielded by BMDP 2V computer programme shows a significant linear trend across testings ($F=40.03$, $p < .001$), which together with inspection of means of each age level for this task (Table 12), indicates an age-related reduction in perseveration errors. A further main effect of socio-economic status is also significant ($F=3.92$, df 1,84, $p < .05$) and this appears to interact with sex ($F=4.65$, df 1,84, $p < .05$). Of considerable interest is the four-way interaction of testings, age, sex and socio-economic status which is represented in diagrammatic form as Figure 10. Interpretation of a four-way interaction is difficult, and particularly since the number of categories achieved,and which increase over age, appears to influence the number of perseveration errors. Analysis of within-task differences indicates significant differences between total errors across the three categories analysed(Tables 53,54,55,56,57). The relationship between perseveration errors and total errors is represented graphically as Figure 26(a,b,c,d,e) for children solving three categories, and as ANOVA(Tables 59,60,61,62,63) in which the proportion of perseveration to total errors is shown to differ significantly between categories. The null hypotheses(i,ii,iii)are rejected.

It is interesting to note that perseverative errors do not rise as sharply between second and third categories achieved, as between first and second categories. The first reversal appears to be more difficult to make,and it is not clear whether the second reversal is easier from learning the task,or that number(the third category) becomes salient for school children. To test this is a matter for further research. It may be that it is analogous to the colour to form shift, listed by White(1965) as one of the developmental changes, which takes place between five and seven years.

The within task differences are likely to be a variable influencing the four-way interaction. In considering this, although Scholnick, Osler and Katzenellenbogen(1968),found that less advantaged children perseverated more than advantaged groups at both 5 and 8 year old levels, results from the present study suggest that, whereas SES is a significant main effect between groups, its influence is differential, according to age, sex and testing. Kagan and Kogan (1970), too found that LSES children behaved more impulsively than USES groups. Figure 10 showing means of each sub-group for the four-way interaction illustrates this point, and some aspects can be seen graphically (Figure 20), from the significant AgexSex x SES Interaction ($F= 3.74$, df 2,84 $p < .05$), drawn from further ANOVA,(Arc-sine)p183. From this, the interaction is observed between the 5 and 7 year old sub-group, when sex and SES differences become least. The differences between socio-ecomonic groups is discussed again in this chapter. However, although inspection of the means, (Table 12), and results of ANOVA show that perseveration errors decline over age, it is to be expected that total errors also decline. It is central to this research to investigate whether the nature of the errors remain in constant proportion, or whether, as would be indicated from the literature, perseveration is succeeded by alternation, and subsequently by more complex patterns. Accordingly, as stated in Chapter 4, Four-Way Analysis of Variance was carried out using proportions of perseveration errors to total errors through Arc-Sine transformation. The results are presented as Table 40, and show a highly significant main effect of age ($F=27.57$, df 2,84, $p < .001$). In the case of the ANOVA using perseveration errors (Table 20), again a significant main effect of socio-economic status is found ($F= 3.92$ df 1,84, $p < .05$). The three-way interaction of main effects of Age, Sex and SES has already been discussed. 'Testings', as a 'within' factor, was significant ($F=3.06$, df 3,252 $p < .05$), consistent with results from the previous ANOVA. There was also Linear Trend ($F=6.64$, $p < .05$), (Table 41). From these results it appears that the proportion of perseveration errors to the total declines in relation to age, and the interpretation is that alternation errors account for an increasing number. Since an insufficient sum of squares remained after taking out Linear Trend, it is concluded that more complex patterns representing a further strategy were not used on this task.

While the null-hypothesis (vii) is rejected in view of the significant main effect ($p < .05$), further investigation is needed to identify features of social experience relating to perseveration behaviour. The null-hypotheses (1) and (2) of no difference between age groups and within children in perseveration errors are rejected, since the main effect of Age, and within factor of testings, are statistically significant (Table 20).

It should, however, be noted that the differences between socio-economic groups may be partially attributable to an artefact of the experimental design, and which is reflected in the sampling procedures (Chapter 3). Wells (1979) has argued, in criticising Bernstein's work (1960) that although social class related differences in language are found, social experience should be regarded as a continuous variable. During the testing procedure, information from the children, and from their teachers, suggested overlap between socio-economic groups in their home experiences. For example, S.43, LSES girl of 5 years, was bought a book each week by her mother who read it with the child. The father, in this case, was an unskilled labourer employed in casual work. By contrast, S.31, USES girl of 3 years, lived in financially comfortable conditions with professional parents, but arrived dirty and unaccompanied at playgroup on a daily basis. Similarly, other cases could be cited. The quality of children's experiences appears to be more meaningful than socio-economic status. This is relevant also to school life, and it is of particular interest that SES differences appear to diminish in Wisconsin Card Sorting Test (Figure 19). The lessening of differences cannot be attributed to ceiling efforts for the test. Even at the fourth testing of the 7 year old group, who had completed their 9th year, fifteen children only had achieved three categories (Table 56). The task used 64 trials and a theoretical maximum of six categories was possible. It is suggested from this, that education exerted a positive influence on the less advantaged group, and this view receives support from recent intervention studies (Beveridge and Jerrams 1981, Hewison and Tizard 1980, Tizard et al 1982).

Implications from the results of Wisconsin Card Sorting Test

The Wisconsin Card Sorting Test has been extensively used in studies of deficit following frontal lobe lesion (see Chapter 1). Loss of capacity to inhibit an ongoing response and modify behaviour according to cues and errors, and therefore a loss of ability to actively reduce error, has been said to characterise frontal lobe lesion in animal and man (Milner 1964, Pribram 1973, Pribram, Plotkin, Anderson and Leong 1977, Christensen 1975, Luria 1973). Vargha-Khadem (1983) reported results, reviewed in Chapter 1, from a comparison of children aged between 6 and 17 years with left or right hemisphere frontal lesion, and normal controls on the Wisconsin Card Sorting Test. As noted in Chapter 1, children who had suffered lesion, pre or post-natally, made approximately twice as many perseveration errors than the control group. Vargha-Khadem suggested that the frontal systems in the normal control group has matured sufficiently for them to achieve a mean number of 4.35 completed categories. Direct comparison between her findings for the normal control group and those from the present study, cannot be made, since in Vargha-Khadem's study, a pack of 128 cards was used, whereas this research used 64, or half pack.

Nevertheless, as inspection of the raw data shows (Appendix 8, micro-fiche) there was an age-related increase in the number of categories achieved. The mean numbers of categories achieved are summarised as Table 79, and with necessary caution in view of the pack size differences, there appears to be comparability between results for the 5 year old sub-group, who, at Testing 3, are between 6 and 7 years chronologically, the 7 year old sub-group, and those reported by Vargha-Khadem for the normal control group.

Table 79 Mean number of categories completed Wisconsin Card Sorting Test

	Testing 1	Testing 2	Testing 3	Testing 4
3 years	.69	.88	1.48	1.6
5 years	1.44	1.59	1.78	2.35
7 years	2.06	2.09	2.5	2.59

In keeping with results from t-tests for practice efforts, discussed on page 240, which reached a .05 level of significance between 5 year olds at Testing 4 and 7 year olds at Testing 1, on numbers of perseveration errors, the mean number of categories achieved shows a difference, suggesting improved performance from practice at this age level.

Spontaneous Alternation

Table 22 shows age to be a highly significant main effect in perseveration scores on the Spontaneous Alternation task ($F=9.64$, df 2,84, $p < .001$). Sex, too, is shown to be significant ($F=5.45$, df 1,84, $p < .05$), and means for this main effect were plotted as Figure 11. These show that boys perseverated more highly than girls on all testings for 3 year old sub-group, but at a near-equal rate at the 5 year old level and which implied that an alternation strategy was being used. However, although the 7 year old sub-group of boys again perseverated more than girls, this may represent, at this stage, a qualitatively different strategy. Kogan (1976) has noted that girls' early advantage in field independence is reversed in favour of boys from the sixth year, and the present results indicate an equivalent reversal of sex-related achievement. The likelihood of more complex patterns, which suggest the elaboration of the developmentally simple perseveration and alternation strategies, was referred to in the preceding discussion, and has been noted in a number of studies, eg. Gellerman (1931), Douglas (1972,1975,1976). In Weir's study of Three Choice Discrimination Learning (1964), he commented that the apparent maximising behaviour of young children and adults was quantitatively similar, but that qualitatively different hypothesis-testing behaviour was likely between the two groups.

The interpretation of perseveration behaviour between the age groups given, is supported by the tests for Trend, which yielded both Linear and Quadratic Trends (Linear $F=58.94$, $p < .001$, Quadratic $F=15.49$, $p < .001$), shown in Table 23, and by the Trend Analysis of the interaction between Testings and Age (Table 24) which showed a significant linear relationship ($F=62.31$, $p < .001$). Similarly, the further Four-way ANOVA, using proportions of perseverations to total trials (Arc-Sine transformation), gave results which support the point, p185. Age and sex are again main effects on this task ($F=6.01$, df 2,84, $p < .01$, $F=5.08$, df 1,84, $p < .05$), but more relevant to the present discussion, are the results of Trend Analysis for Testings which was carried out following a highly significant F ratio ($F=28.74$, df 3,252, $p < .001$). Linear Trend was significant ($F=55.73$, $p < .001$) and so, too, was Quadratic Trend, ($F=17.81$, $p < .001$). The means for Trends have been plotted as Figure 12, and provide evidence of a perseveration-alternation-complex direction in strategy use, and which is further supported by the Trend Analysis of Testings with Age ($F=60.10$, $p < .001$), Table 44.

It is of interest to note from Figure 12, showing Interaction between Testings, Age and SES, that the p rseveration scores of upper socio-economic groups at three years level out at the third testing, whereas those of the lower socio-economic groups are still decreasing. The implication from this appears to be that, at the youngest age level, upper socio-economic status children are more advanced in their strategy use, and at this stage the results would agree with those of Scholnick, Osler and Katzenellenbogen (1968). Since this task has been considered to reflect hippocampal function, and the onset of internal inhibitory ability (Douglas 1972, 1975, Glanzer 1953, Clayfield 1976), it is possible that upper socio-economic status children achieve this earlier than their less advantaged counterparts. However, a different interpretation of the nature of inhibition and hippocampal involvement is offered in the final section of this chapter, but although it is outside the scope of this study, the interesting question of the relationship between social experience and postulated central nervous system maturation is raised.

As a result of these analyses, the null hypotheses (3,4) of no difference between age groups of children, or within children in perseveration scores is rejected, and those also (Hypotheses vi, vii) relating to sex and SES differences are not supported.

Further implications from administration of the Spontaneous Alternation Task

As was discussed on p 240 of this Chapter, t-tests for practice effects were carried out for all tasks separately. Those for 3 year olds at Testing 4, and 5 year olds at Testing 1, on the Spontaneous Alternation Task, and which showed a significant difference in mean perseveration between the two sub-samples ($t=3.37$, $p<.05$). The expectation that this would occur is not provided by the literature.

Glanzer (1953) had noted that performance on a spontaneous alternation task was not influenced by habituation, Frith 1970a, 1970b, who used a similar task, but with visual feedback information, also considered that information did not alter performance. That Frith's view cannot be sustained is indicated by the comparison of results of the pilot study carried out for this research, which showed a lower level of perseveration when cards were seen after each guess, (Appendix 1). However, Frith's work, like other relevant studies on children(Douglas 1972,1975,1976, Reed, Pien and Rothbart 1984) was cross-sectional, and thus the issue of practice efforts would not have arisen.

It is suggested that the repeated administration of the task perhaps gave confidence to the 3 years olds at their fourth experience of the task, which the 5 year olds may have lacked at their first, although Schultz(1964) hypothesis is considered later. The temporal stacking model of cognitive competencies provided by White (1965), in which lower level competencies would be disinhibited, is relevant here. Egelund(1974), following

Denney's (1972,1973) work attempted to train impulsive children to behave in a more reflective way and found that stress produced a regression.

The implication from use of Spontaneous Alternation are discussed further in the final section in relation to the evidence for inhibition and the processes of strategy development (eg. Flavell 1972, 1977).

Oddity Problem

The series of Four-way ANOVAs carried out for perseveration errors (Wisconsin Card Sorting Test) and for perseverations (Spontaneous Alternation), and on proportions of these(error or scores) to total errors or trials, was repeated using as the dependent variable, equivalent scores obtained from administration of the Oddity Problem. Again, a highly significant main effect of age is shown (Table 25), (with $F=40.39$, df 2,84, $p < .001$). Testings, as a within factor, is also significant ($F=16.06$, df 3,252, $p < .001$), and this factor interacts with age. The Trend Analysis of Testings showed significant Linear ($F=31.00$, $p < .001$), and also Cubic ($F=5.29$, $p < .05$) Trend . (Table 26).

The cubic trend would appear to be accounted for predominantly by the 5 and 7 year old sub-groups, whose performance on the four testings is not dissimilar. Similarly, the interaction effect is most pronounced between these two groups, and it should be noted that the graph (Figure 13), for the 3 year old sub-group indicates so marked a difference from the other two groups that it can be interpreted as qualitative. Trend Analysis of Interaction between Age and Testings (Table 27) indicates a significant linear trend (11.37, $p < 001$). From the further ANOVA using arc-sine transformations of perseverative to total errors, (Table 45), which shows age to be the only significant factor ($F=12.76$, df 2,84, $p < .001$), it would appear that perseveration errors reduce with age. Complex strategy patterns are not apparently used in this task, since their presence to a significant degree would be revealed by non-linear quadratic trend in the analyses. This is discussed further in the final section on inhibition and strategy change.

Implications from results of the Oddity Problem

Results from administration of the Oddity Problem to the 96 children in the research sample on four test occasions give support to the findings from the literature. Harlow and Harlow (1949) considered that acquisition of a learning set using an Oddity Problem required the subject, infra-human or human, to overcome response tendencies to perseverate or alternate. Both forms of ANOVA carried out to test the hypotheses relating to this task, have supported this. Perseveration declined with age in both an absolute sense, and in the relative sense of proportions of perseverations to total errors. Residual errors were therefore of an alternating type. Age-related increase in ability to attain the learning set was shown, and is further discussed in the section on language change in problem solving, for inferences to be drawn on modes of processing information. However, Harlow's use of oddity problems was concerned not only with normal development in animals and man, but with the application of the task to the study of frontal lobe lesion, and related cognitive deficits. Whilst, in the review of literature the pitfalls of extrapolating from animal to man have been discussed e.g Gale (1980), nevertheless, the age-related increase in successful solutions shown in this study, does suggest an increase in internal inhibitory ability, since the null-hypotheses (5,6) are not supported by the results.

Other aspects from use of Oddity Problem

The procedure used in the administration of this task also enabled a separate study of developmental changes in modes of representation (Clayfield and Davis 1984). In this, four levels of solution were identified, discrimination learning, generalisation, imaging and verbal justification of the oddity concept. The results of this, and the implications, are discussed in the section on the relationship of language to problem solving. (Also see Appendix 7).

Two-choice Discrimination Learning

Four-way Analysis Variance Table 28, shows Age to be a significant main effect ($F=6.76$, df 2,84, $p < .01$) and that Testing is a significant within factor ($F=5.5$, df 3,252, $p < .01$. Further analysis for Trend across Testing occasions, Table 29, gave a highly significant linear trend ($F=7.65$, $p < .01$) and that the interaction of Age with Testings was also linear, Table 30 ($F=3.76$, $p < .05$).

The relationship between proportion of perseverative to total errors was also analysed by Four Way ANOVA. No significant results were shown,as expected,since the task was a simple one,as is indicated by its low contribution to the variance for Factor1,Tables 4,6,8,10 and from Figure 14, of interaction between Testings and Age.This interaction may, in part,be accounted for by the significant practice effect between 5 year olds at Testing 4 and 7 year olds at Testing 1. Clearly, in spite of the lack of difficulty in the task, some learning occured at this stage.

Since ANOVA gave significant results, as stated, the null hypotheses (7,8) relating to difference between age groups, and within children, are rejected.

Implications from administration of Two-Choice Discrimination Learning Task

In this simultaneous discrimination problem, reinforcement is contingent on each correct response (Goulet and Goodwin 1970). The task carried high information value, which should facilitate active reduction of error. Table 64, page 205 , of within-task differences on this task shows that most perseveration errors are made on the first condition given, irrespective of whether this is the reversal or non-reversal condition. It would thus appear that the children at all ages are learning early in the task to obtain reward, albeit less easily at the younger age level. The null hypotheses (iv,v) are not rejected. Although a Two-Choice Discrimination Learning Task has been used by a number of workers in the internal inhibition field of study, and which has been linked to studies of frontal lobe functions (eg. Lynn and Compton 1966), it would not appear to be a good discriminator of children's ability to reduce error, and therefore of planning abilities. Pribram (1973) has shown that even frontally lesioned monkeys can learn a simple discrimination problem. He also found (1971) like Douglas (1972,1975), that hippocampal-tomised animals who are thus thought to lack internal inhibitory capacity, can learn by reward, and, conversely, amygdalectomised animals lose this ability. The 2-choice Discrimination Learning Task used in this study may, too, reflect the children's ability to use passive, rather than active, inference (Bryant 1974), particularly in view of the more recent finding of Bryant's(1982) that children learn more readily from confirmation of a strategy than from its refutation in a measurement task.

Three-Choice Discrimination Learning

One of two conditions of reinforcement schedule was given to half the total sample, and the sampling procedure is decribed in Chapter 3. Results from each have been analysed separately and are discussed in turn, before considering the implications of both, in relation to the literature, and for the hypotheses of the present study.

Results from use of a 66% reinforcement schedule

Age is shown, from Four Way Analysis Variance, Table 31, to be a significant main effect ($F=16.26$, df 2,36, $p < .001$) and also the within factor, Testings ($F=12.39$, df 3,108, $p < .001$). Both

Trend for Testings, and for interaction of Testings with Age are analysed, and results are presented as Table 32 and 33. A significant linear trend is found ($F=23.22$, $p < .001$) for Testings, but for the interaction effect, both linear ($F=7.96$, $p < .01$), and cubic trend ($F=6.40$, $p < .01$), describe the relationship between testings and age. Figure 15 suggests that the 7 year old sub-group contribute substantially to the cubic trend. The means for the 3 year old group are visibly higher than those for 5 and 7 year olds, and the psychological significance of this is discussed in the final section.

These results are given further support from the ANOVA, using transformed data (Arc-Sine), Table 46, and again a main effect of age is shown ($F=21.94$, df 2,36, $p < .001$). The within factor, Testings, is also significant ($F= 15.32$ df 3,108 $p < 001$). Means for the two-way interaction have been plotted, (Figure 23), and results of Trend Analyses (Table 47 and 48) are consistent with those from analysis of raw perseveration errors.

A main effect of sex is shown by the use of transformed data, Table 46, ($F=6.93$, df 1,36, $p < .05$) and means for this are plotted as Figure 22. These illustrate that boys make more perseveration errors as a proportion of their total errors at all ages than girls, with the least difference shown in the testings for the 5 year old group. The point made in relation to similar findings from Spontaneous Alternation Task is relevant, and, developmentally, the early lag by boys again appears to be levelling out. It is suggested, as for the Spontaneous Alternation Task, that boys at the 7 year old level are beginning to test more complex hypotheses, particularly in the less structured 33% condition and qualitative evidence from children's comments is discussed in the section on language change in problem solving behaviour.

Results from the use of a 33% reinforcement schedule

Table 34 shows a highly significant difference between the three age groups ($F=33.87$, df 2,36, $p < .001$), and for the within factor, Testings, ($F=12.81$, df 3,108, $p < .001$). Trend Analysis has been carried out, and Table 35 shows a highly significant linear trend ($F=42.71$, $p < .001$). Unlike Trend Analysis for the 66% condition, which showed cubic in addition to linear trend, analysis of 33% condition left insufficient sums of squares for any non-linear trend. The significance of this is discussed in the following section, implications.

The two-way interaction of Testings with age is also significant ($F=7.48$, df 6,108, $p < .001$), Table 36, and means are plotted as Figure 16. Further implications of this will be drawn out in the section to follow, but it is of interest to note from the graph that perseveration errors of the 7 year old sub-group are virtually the inverse of those in the 66% reinforcement condition.

A significant four-way interaction is shown, and is drawn as a tree diagram, Figure 25. The complexity of a four-way interaction is such that it is best interpreted as reflecting differential influences of age, social, and experiential variables on development over time. The sub-sample tested on this condition is small at each age level. This, together with the substantial sum of squares attributable to error, suggests that individual differences also affect performance. These are discussed further in discussion of individual curves (Hindley and Owen 1979). Results from the further ANOVA carried out on arc-sine transformation of proportion of perseveration to total errors, give added support to the main findings for the 33 reinforcement condition of this task. Age is significant ($F=48.96$, df 2,36, $p<.001$), Table49, and so, too, is Testings ($F=10.22$, df 3,108, $p<.001$). Trend Analysis, Table 50, yields a significant linear trend ($F=20.46$, $p<.001$). Further Trend Analysis, following a significant interaction of Testings with Age (Table 51), show both significant linear trend ($F=6.8$, $p<.01$) and also quadratic trend, ($F=4.22$, $p<.05$). This is plotted as Figure 24 Two points are of interest, and are discussed in the following paragraphs. First, that quadratic trend is found, using proportion data, but not in analysis of raw perseveration errors. Secondly, that comparison of the interaction trends with those of the equivalent analysis on the 66% reinforcement condition shows cubic in addition to linear trend. From the quadratic trend found in 33% condition, it is suggested that in this less structured condition, children are more likely to impose their dominant strategy of perseveration, alternation or complex patterns.

<u>Implications from results of 66% and 33% reinforcement Conditions</u>

The four Four-way Analysis of Variance carried out for the two reinforcement conditions give results which lead to the rejection of the null-hypotheses (9,10) of no difference between ages, or within children.

Perseveration strategy in the 33% condition does suggest that inhibitory ability reflected by the ability to utilise cues and errors is more limited than in the 66% condition. This is consistent with the literature reviewed for this study (eg. Pribram 1973, Luria 1973).

The findings, similarly, are consistent with those of Abe (1975) who replicated Weir's (1964) work using a Three-Choice Discrimination Learning Task. Whereas Weir found a higher number of correct responses in this 3 year old group and young adults than for the 5,7,9,11 and 15 year olds who tended to alternate, Abe's results showed higher adverse levels of position perseveration at 3 years. For this age group, Abe's results were in direct contradiction to Weir's, but with more agreement at the 7 and 9 year level.

Weir's (1964) work and that of Abe (1975) is reviewed in Chapter 1, and it was noted that Weir's 3 year old subjects appeared to be unusually able, for their age level, to utilise cues and errors and switch response appropriately, or that they were fortunate enough to choose the correct knob at the outset. The children in the present study were far less successful, and where an early incorrect choice was made, it was frequently repeated for long runs. This occurred in spite of giving a prompt in such cases, 'Remember, try to win as many marbles as you can'. Like the children in Abe's study, the 3 year olds in the present work could be categorised as correct or incorrect perseverators rather than effective problem-solvers. It was suggested in Chapter 1, that the form of words used by Weir and co-workers (Stevenson and Zigler 1958; Stevenson and Weir 1959,1963; Weir 1962,1964; Gruen and Weir 1964) misled the 5,7,9,11 and 15 year old groups. It is further suggested that the instructions used in the present study avoided the methodological flaw which continued throughout Weir's work (1965,1967,1968). Children in this study were told 'Every time I lift the window, you choose one of the cubes. The game is to win as many marbles as you can'.This instruction would seem to be more neutral than those of Weir and his colleagues who instructed children:

> 'when the light comes on, you push one of the knobs. If you push the correct knob, a marble comes out here like this. Now, every time the light comes on you push the marble. Remember, just push one knob each time the light comes on'(Stevenson and Zigler 1958).

The children would clearly have been led to expect that reward would be 100% to the correct choice, and their behaviour, over the age-range tested, would have reflected that hypothesis. In fact, reward could only be obtained 66% or 33% of the time. One further possibility, referred to in Chapter 3, is that the centrally placed light signalling the start of a trial, may also have been misleading. However, this is less plausible as an explanation, than that concerning the instructions.

In spite of the methodological criticisms levelled at the work of Weir, it may have hastened the process of considering the possibility that qualitative, and not only quantitative differences, are implicated in age-related performance differences on discrimination and probability taks. Weir (Stevenson and Weir 1963) in one study, asked the children to verbalise the reasons for their choice. A variety of reasons were given, including 'I'll push this one, because I haven't pushed it for a while'.

In the present study, following completion of the task, children at random were asked how they knew which cube to choose. Their replies were recorded. S79 (7 year old LSES girl - 66% condition) replied 'I was choosing it, two of those and them (points) and then two of those'. S55 (5 year old USES boy, 33% condition) 'I knew I would find it again because it wasn't moving so often'. When asked whether he thought the correct cube moved, he replied 'Yes' and pointed left,middle,right. This child's accuracy improved to 14 correct out of the final 20 trials. Expectation of pattern is shown by S55's response, and this had confirmation from Weir (Gruen and Weir 1964). From this, it is possible that some features of the task procedure had differential interaction with age, or preferred strategy of some children. The literature provides support for the view that, when the demands of the task match the operating rule of the children, performance is enhanced (Goulet and Goodwin 1970). More currently, this question of the match between task and child is the subject of educational concern (Bennett, Desforges, Cockburn and Wilkinson 1984, DES 1978,1982,1983).

Implications for development of inhibitory processes

Perseveration has been argued to be a primitive strategy, and facilitates success in problem solving only if the demand of a task match with it. The 3 and 5 year olds (Weir 1964) and three year olds in the present study were, in effect, repeating a response, whereas the older children were alternating responses across the three knobs. If the theory developed by Bogartz (1966), to explain repetition and alternation in binary prediction, is applied to the three choice problem, then the response repetition of 3 year olds in this study (and also by 5 year olds in Weir's work 1964), would exemplify a one trial memory when the same response is put into STM store on each occasion and its trace leads to a repetition of the first available response. This is a similar account to that of Restle (1962). On the other hand, alternation would be accounted for by rudimentary development of inhibitory processes, whereby the most recent response is attended to, remembered, and the alternative is chosen. However, the assumption of limited memory ability is questionable. The literature reviewed, and final section of this chapter indicate considerable memory competence in young children. The alternation strategy used by 7,9,11 and 15 year olds in the studies presented by Weir (1964) and that used by 5 and 7 year old children in the present work is nevertheless seen as developmentally more advanced than the response repetition shown by the younger children.

The Attributes Task

Four-Way ANOVA carried out for this task, using perseveration errors as the dependent variable, showed Age to be a significant main effect, (Table 37, F=20.94, df 2,84, $p < .001$). A similarly significant result is yielded from the further ANOVA using transformed data of proportions of perseveration to total errors (Table 52) F=15.53, df 2,84, $p < .001$). Testings is a significant within factor in perseveration errors (Table 37, F=29.84, df 3,252, $p < .001$) but not when analysed, using transformed data. Trend Analysis was carried out for the significant Testings result, and Table 38 shows a highly significant linear trend (F=62.54, $p < .001$). A two-way interaction of Testings with Age in perseveration errors is significant (F=3.07, $p < .01$) and this is plotted as Figure 18, before analysis for trend (Table 39). Linear Trend is significant (F=4.67, $p < .05$). The two-way interaction is not shown from the ANOVA using arc-sine transformation of perseveration error proportions, but a four-way interaction of Testings, Age, Sex and SES is significant (F=2.47, $p < .05$),p196. This is plotted as a tree-diagram (Figure 25). Both position and stimulus perseveration and alternation were observed, as would be expected from the prototypical work of Levine (1966), although this was not considered a source of confusion in subsequent studies of Eimas (1969), Gholson, Levine and Phillips (1972), Phillips and Levine (1975), Cantor and Spiker (1978) and Spiker and Cantor (1979).

This may have served to accentuate interaction,but except where a child verbalised choice behaviour eg.S50(5 year old boy USES)'A lot of words begin with x so I choosed it'(sic), differential forms of perseveration,or alternation,could not be separated without making subjective judgements. Additionally,and to be discussed in the section on language change in problem solving,verbalisation after the event is not necessarily reflecting the strategy used at the time(Zeiler 1967 .Further implications are discussed in the following paragraphs.

From the analysis of perseveration errors,the null hypotheses (11,12) of no difference between age groups,or within children are rejected. The significant main effect of difference between age groups from the ANOVA,using transformed data,gives added support to the decision to reject the null hypothesis relating to age.

<u>Implications from use of the Attributes Task</u>

From the results of analysis for this task,perseveration to position or stimulus,appears to be the dominant strategy of the 3 year old group,and during the two years of testing that this group,like 5 and 7 year olds,begin to utilise an alternation strategy.The results support those found in the literature. Gholson,Levine and Phillips(1972),following the original work of Levine(1966), suggested that a system (sy) is used in hypothesis testing and that the system becomes more sophisticated over time,following the use of early stereo typed response patterns of perseveration,alternation and subsequent stimulus preference. The order suggested was that stimulus preference is followed by hypothesis checking, dimension checking and focussing, and this formulation draws on the work of Bruner, Goodnow and Austin (1956). Identification of these systems (sy's) was claimed to be possible from use of a more ambiguous set of materials than were used in the present study. Gholson et al (1972) used cards which contained more than one attribute, and either black or white, shape of T or X, and line up or down position were presented on each trial. The criticism which can be levelled at the classic Kendler (1963) task of presenting large or small black or white cards as a means of testing reversal or non-reversal shift is opposite here, since one possibility is that the child may respond to a Gestalt. It is suggested that confusion over how to classify responses led to the difficulties experienced by Gholson, Levine and Phillips (1972) in analysing their data, and to the elimination from their experiment of some second grade children who did not solve preliminary problems.

The study is nevertheless useful for its detailed discussion of possible processes, in particular, Restle's (1962) theory of 'zero memory' which was reviewed in Chapter 1. The blank trials procedure used by Gholson et al (1972) allowed the investigation of whether a hypothesis was retained or abandoned during non-reinforcement trials. Their conclusion was the children of all ages tended to abandon a non-reinforced hypothesis, but that elementary school age children replaced the faulty hypothesis in their 'pool', with the possibility of re-sampling. Resampling of a returned hypothesis leads, then, to its possible re-use from perseveration or alternation, which, it is suggested here, becomes less likely as children develop the ability to use the cues provided by a problem, and modify behaviour by active reduction of error. The development of inhibitory ability has been argued to be a necessary condition for flexible problem-solving. However, it is possible that practice facilitates the reduction of errors, and it is suggested that practice may interact with maturation of cognitive competencies. Table 18 and 19 show practice effects between both sets of overlapping age samples, 3 year olds at Testing 4, 5 year olds at Testing 1 ($t=2.16, p<.05$) and of 5 year olds at Testing 4 with 7 year olds at Testing 1 ($t=3.08$, $p< .05$).

This finding, and hence the inference concerning practice effects, is consistent with the results from Cantor and Spiker (1978), and Spiker and Cantor (1979). In these two studies, it was found that training on the use of hypothesis testing increased the proportion of children who utilised systematic problem-solving strategies. As a caveat, the training and experimental trials took place consecutively. No delayed post-test was carried out, so no clear cut conclusion can be drawn whether improved performance endured over time. However, these findings do raise again the question of the relationship of experience to maturation of function, but which is beyond the scope of the present study.

The relationship between Pre-tests and Experimental Tasks

Correlation co-efficients were computed for scores on pre-tests (Coloured Progressive Matrices, Reynell Language (Verbal) Comprehension Sub-scale, Matching Familiar Figures Latency, the number of first correct responses on MFF and the experimental task battery,)separately for each age group and testing. Twelve correlation matrices were thus derived, and these are presented as Table 67 to 78 inclusive. Inspection of these show that the Coloured Progressive Matrices correlate significantly with Language Comprehension at 3 and 7 years, but not at 5 years, with MFF Latency scores at all ages, and with MFF number of first correct responses at 5 and 7 years only. Language comprehension correlates with the MFF test only at 3 years, and for the number of first responses correct. The inter-correlation of experimental tasks with each other, and with the pre-tests, is only moderate, and differential across ages and testings. They are sufficient, however, to reject hypothesis viii. No clear pattern is discernable, and some possible explanations are suggested.

First, the separate correlations for each age level and each testing are from more homogeneous samples than would have occurred if all cases had been entered into the analysis. The sample is, in any event, relatively homogeneous from the sampling procedure, and this is considered to lower the correlation between the variables. In the initial sampling, following pre-tests, three boys, all of lower socio-economic status were excluded. One, a five year old, was thought to be of particularly low ability, and with a language sub-scale score that suggested a two year old level of competence. The further two were excluded, both seven year olds, because of severe learning disabilities, and who were being referred for specialist advice. Five others, (two at five years, and three at three years), were substituted for further children during the period of the the first testing, as their attendance at school was so variable that certainty of testing them, within the time constraints, could not be ensured. Secondly, and relevant to the low correlation of language with RCPM at five years, is the finding that lower SES children's language standard scores were more likely to be negative, and apparently below their non-verbal intelligence (Ravens Coloured Progressive Matrices) than those of the upper SES groups. This is a feature noted in socio-linguistic research (eg. Bernstein 1960, Lawton 1968), but it may be that the language test is a poor one for inner city children. One sub-test in the Reynell test uses models of animals, which have to be placed in relation to others, on the instructions of the experimenter. Although the sub-test purports to test understanding of prepositions, it was apparent during testing that a number of children were unclear about the animals' names. Several, for instance, referred to the pig models (both black and pink) as guinea pigs. It may be that their lack of familiarity with phrases like 'pink pig' or 'black pig' reduced performance. It is suggested that the importance of contextual access to learning needs to be taken in account in designing research across sub-cultural groups, and that published tests, particularly in language, do not adequately reflect this. There is a growing body of research which illustrates this point. Freeman, Lloyd and Sinha (1980) show that twelve and fifteen month old babies search for a hidden object is more efficient if a cup is upright than when it is inverted. Similarly, the work of Gelman and Gallistel (1983) and Michie (1984) with pre-school children's number concepts, and that of Donaldson (1978) in perspective taking, are exemplars. A third point, in partial explanation of the low inter-correlations between experimental tasks, is of central concern to the aims of this study. It would appear that there are both age-related differences between children, and within children, in the strategies used on all the tasks. However, there are specific aspects to these, which have differential outcomes in utilisation of strategies, as is shown in the next section.

Individual curves and their significance

Individual curves have been drawn for each child's perseveration scores on each of the four testings for two of the experimental tasks, Wisconsin Card Sorting Test, and Spontaneous Alternation. These two were selected, since Wisconsin Card Sorting Test is thought to be the task which most clearly reflects planning ability, and the active reduction of error. It also represents a classic task used in studies of frontal lobe function. The Spontaneous Alternation Task, of its nature, has no externally imposed requirement for planning, and allows the imposition of the child's dominant strategy (Frith 1970a,1970b). It has, further, been argued to indicate active hippocampal function and inhibitory ability (Douglas 1972,1975,1976, Reed, Pien and Rothbart, 1984).

Samples of individual curves are included in Chapter 4, and the graphs for all children have been transferred to micro-fiche. From the separate curves for each of two tasks, groups of curves have been identified, and the drawings for these are included in Chapter 4, Figure 27, Curve types 1-6 (Wisconsin Card Sorting Test), and Figure 28, Curve types 1-8(Spontaneous Alternation Task).

For identification and discussion purposes, a key is given, of subject number, sex and SES in columns of age levels. The procedure used in drawing and grouping the individual graphs is one justified by Hindley and Owen (1979). They stated that

> 'examination of the nature of individual curves is logically prior to an attempt to combine them',

and that the

> 'shape of each individual's curve is characterised in terms of appropriate mathematical parameters and in terms of qualitative 'by eye' judgements. Both methods are descriptive, and both permit frequency counts of similar curves'.

They further state in conclusion that the method of visual classification used in grouping individual development curves was a successful one in accounting for much of the systematic variation. Furthermore, it is an easily applicable means of analysis for developmental data, which takes account of the trend for individuals. From the justification provided by Hindley and Owen, since both methods, statistical and visual, are descriptive, it is considered that no advantage is gained by statistical analysis of the individual curves obtained in the present study.

The age levels contribute unequally to the curve types, and the distribution is summarised as Table 80, for Wisconsin Card Sorting Test, and Table 81, for Spontaneous Alternation.

Table 80 Curve Type - Wisconsin Card Sorting Test

Age	1	2	3	4	5	6
3 years	7	10	2	6	7	0
5 years	12	8	5	4	2	1
7 years	10	6	9	4	2	1
	N=29	N=24	N=16	N=14	N=11	N=2

From Table 80, it can be seen that 69 children from the total of 96 are included within curve types 1,2 and 3, but that the variation between,and within, curve types are indicative of considerable individual differences in development. This is further discussed in this section following discussion of specific results from curves drawn from the two tasks. Some aspects of individual children's performance are of interest. Curve type 1 includes seven children aged three years at the start of the study, and, of these, all except S10 GL, were intuitively judged by the writer to be able children. S10 was difficult to test on the first testing occasion, and thought to be timid. Her home circumstances were reported by the play-group leader to be unsettled, with even the possibility of non-accidental injury to her. It will be noted that five of the seven children at 3 years are USES girls, and of these, S27 achieved well on number of categories completed (2 - Testing 1, 3 - Testing 2, 3 - Testing 3, 3 - Testing 4). It is thought to be of relevance that her scores in pre-tests were above average. On RCPM, she scored 10, whereas the mean for her age level was 8, (range 4-15), on the language comprehension subscale, the standard score =0.8 ($\bar{x}$ = -0.02). MFF Latency score = 5.16($\bar{x}$ = 4.26), and number of first correct response in MFF - 3($\bar{x}$ = 1.71 . She is the subject of further discussion in relation to modes of representation in language and problem-solving, but for the present purpose, this child is also a member of curve Type 1 for Spontaneous Alternation (Table 81).

Table 81 Curve Type - Spontaneous Alternation

Age	1	2	3	4	5	6	7	8
3 years	6	15	5	3	2	0	1	0
5 years	11	4	6	5	5	1	0	0
7 years	11	5	3	5	4	2	1	1
	N=28	N=24	N=14	N=13	N=11	N=3	N=2	N=1

From Table 81, it can be seen that 66 children from the sample total of 96 are represented by Curve types 1,2 and 3. Inspection of Curve type 1 shows that subjects S1, S27 and S30 are again included in a curve type more heavily represented by 5 and 7 year olds. By contrast, curve type 2 contains almost half of the 3 year old sub-sample, in which the curve shows a linear decline in perseverations made on this task. One 7 year old (S65BL) included in this curve type, merits comment. He lost much of the sight of one eye in a street play accident between Testings 3 and 4, and his performance in the levels of solution on the Oddity problem showed a regression. This was referred to further in the discussion of language in problem solving. There are implications of this for educators, and the importance of continuing identification procedures for children with special educational needs (Committee of Enquiry 1978).

Constancy and Variability in Individual Development

The literature reviewed in Chapter 1 pointed to both consistency and variability in human development. Clarke and Clarke (1984) have argued that constancy within and between individual development is not a tenable assumption and it is suggested here that not only do the curve drawings, but also the low to moderate inter-correlations between tasks, indicate substantial variability as well as constancy. From the curves drawn for Wisconsin Card Sorting Test and Spontaneous Alternation, the argument by Kendler (1979) that cross-sectional study is a valid substitution for longitudinal study, through the use of logarithmic calculation, to predict future development, cannot be sustained. It may be tenable for inferences to be made between age groups, but not for change within children. Both these are central to the present study of strategy development, and are a justification for the design, and for the range of statistical and qualitative forms of analysis used. In particular the variation within and between individuals suggests that the mean square for error within which is substantial for some tasks, is attributable to individual differences. These are likely to be influenced by intellectual development, and also by personality variables including cognitive style (Kagan 1965a) (Kagan, Moss and Siegel 1973).

Language Change in problem-solving

The literature has indicated that considerable change takes place in children's ability to use language, their own and that of others, in problem-solving. The classic work of Luria (1961), and which was reviewed in Chapter 1, has suggested a dissociation between language and the regulation of behaviour. Sharp (1983) presented evidence from his own work, and from a review of the literature, which suggested that Luria's conclusions were drawn as a result of his methodology. He suggested that dissociation is more appropriately thought of as a function of the relevancy of verbalisation to the task, as perceived by the child. However, from the present study, when verbalisation was not demanded from the child during the test procedure, spontaneous comments were made by, particularly, the 3 year old group, which are indicative of dissociation. In Wisconsin Card Sorting Test, the tester states 'right' or 'wrong' to each card sort. Several children e.g. S25GU, commented that they were wrong during the placing of cards, but appeared unable to modify their behaviour. Analogous findings were reported by Milner (1964) who noted that the frontally lesioned patients often knew they were wrong, but were unable to shift from perserverative response.

In normal child development, Luria considered that verbal regulation of behaviour becomes functional from around four years of age, and this view, as was discussed in Chapter 1, influenced Kendler and Kendler in their work on reversal and non-reversal shift behaviour (1963) and on inferential behaviour in children (1967).

However, the sense in which Luria discussed verbal regulation, and the verbal mediation hypothesis of Kendler and Kendler, are not synomymous. Kendler and Kendler postulated that covert verbal mediation could be identified by asking children to verbalise their responses, and that non-mediators would be less articulate than mediators. This is a dubious concept, since from the work of Piaget (1964) and from Bruner (1956), it appears that language may not accurately reflect behaviour. This would also be predicted from Flavell, Beach and Chinsky's (1966) production deficiency hypothesis, that language competence does not always match performance. The reasons for choices elicited from a random sample of children during the present study, when some were asked 'how did you know which one to choose' and which have been quoted in discussion of specific tasks, illustrate this point.

A separate investigation of levels of solution achieved in the Oddity Problem suggests progressive age-related emergence of ability to make a discrimination, (DIS), generalise it to other instances, (GEN), represent it in image form, (IM), and ultimately to use language to reflect behaviour through verbal justification, (VJ), (Clayfield and Davis 1984). The raw data is given here as Table 82.

Table 82 Raw number of passes at each level of solution of Oddity Problem by age groups and testing

Age	Testing 1				Testing 2				Testing 3				Testing 4			
	DIS	GEN	IM	VJ	DIS	GEN	IM	VJ	DIS	GEN	IM	VJ	DIS	GEN	IM	VJ
3 years	3	0	0	0	7	2	1	0	3	6	5	3	24	11	10	8
5 years	22	18	15	10	25	21	15	13	31	25	22	21	32	29	28	21
7 years	26	24	23	20	29	28	25	26	32	31	30	28	31	29	29	29

Analysis between levels of solution for testings at age level by Cochran Q test revealed significant differences for all except the seven year old group at their second and fourth testings. Q values are given as Table 83.

Table 83 Results of Cochran Q tests for significant differences between levels of solution on Oddity Problem at each age level and testing

Age	Testing 1		Testing 2		Testing 3		Testing 4	
	Q	P	Q	P	Q	P	Q	P
3 years	9.0	.05	15.8	.001	20.6	.001	35.9	.001
5 years	22.4	.001	23.7	.001	18.0	.001	21.6	.001
7 years	11.8	.01	6.6	n.s.	8.0	.05	6.0	n.s.

There were only five exceptions of the total sample of 96 to the developmental trend revealed by the data. Four were girls from USES group. All were considered by their schools to be bright, including S27 discussed in relation to curve types. Each of these gave verbal justification before being able to image, which raises the possibility of individual differences in preferred mode of processing, and is a issue relevant to the school curriculum. The question of meeting special educational needs has been discussed from the case of S65, a LSES boy from the 7 year old group, whose eye accident may have contributed to his regression at the fourth testing.

The evidence cited from further investigation of the Oddity Problem is consistent with the example by Luria (1961) that language more effectively regulates behaviour in 4 year old children when an image is conveyed.

From the discussion of language change in problem-solving,although it appears that these two aspects converge during the age period studied from 3 to 9 years, how far language is cause or correlate of inhibitory ability, the question raised by White (1965) is not illuminated. There are, too, discrepancies between children's abilities to use cues and errors in communicative situations, and the limited ability to do so in the problems used as experimental tasks in this study, and which are supported by the literature reviewed. Shatz and Gelman (1973) showed in three studies that 4 year olds adjusted their speech to the age of their listeners. Speech to 2 year olds contained more short simple utterances, whereas speech to peers was similar to that to adults. It may be that experience as a communicator has facilitated competence in utilisation of feedback from the listener and that this leads to a special case of 'decalage'.

Inhibitory ability and strategy change

The observed discrepancies between the communicative competence of 4 year old children in taking account of their listeners, and their poor performance in discrimination learning, probability and concept attainment tasks, such as those used in the present study, and well-documented in the literature, need explanation. The Piagetian terms of vertical and horizontal decalage are descriptive, rather than explanatory. From the studies reviewed, it appears that some form of inhibitory ability is manifested across a range of behaviours. Demetre(1984) provided evidence of manipulative ability in sixteen month old infants.Schaffer(1974) postulated a form of inhibitory function as accounting for a child's behaviour from incongruity in the presence of strangers. Similarly, if perseveration strategies are to be understood as reflecting a lack of inhibition, then the ability of babies and young children to vary their search behaviour is evidence of some inhibitory competence. The ability to search more than one location has been shown by Butterworth and Jarrett (1982), Sophian and Wellman (1983), although an age relationship can be observed. Twenty-seven month old children search more effectively than twenty-one month old children for a hidden toy (De Loache and Brown 1984). From such studies the 'zero memory' hypothesis formulated by Restle (1954) is difficult to sustain in respect of pre-school and school-age children's cue learning ability, if much younger children do not exhibit 'zero memory'. Studies of meta-memory would suggest considerable memory competence, although Cavanagh and Perlmutter (1984), in a review of the literature, consider that the concept of meta-memory is not well-defined. It may be that some explanatory power is given if inhibitory ability is thought of as undergoing differentiation within progressively higher levels of function. Within a level of function, the nature of the task, and the experience which a child brings to it, are suggested as important.

The example cited earlier of twelve and fifteen month old babies' ability to locate a hidden object in an upright cup, apparently using the rule that only something the right way up can hold an object, served to illustrate the point (Freeman, Lloyd and Sinha 1980). Some aspects of practice effects noted in the present study, may thus be explained in terms of familiarity.

In particular, it appears a possible explanation of the practice effect found between 3 year olds at Testing 4 and 5 year olds at Testing 1 on the Spontaneous Alternation Task. Schultz (1964) reviewed the literature to that date on spontaneous alternation , and concluded that the phenomenon represented a seeking after novelty, and which serves to maintain alertness. By the fourth testing, maintaining alertness, which Hebb (1949) saw as important in motivation, may have been attained by alternation. By this stage, the 3 year old group were 5 years chronologically, with alternation becoming their dominant strategy. Conversely, for the 5 year old group at Testing 1, the task itself and the testing situation may have been sufficient to maintain alertness, which has potential for learning.

The registration of novelty and use of non-reinforcement was argued by Douglas (1972,1975,1976) to be the function of the hippocampus, which he suggested from results of experiments on normal and lesioned animals and, with his wife, on young children, using a Spontaneous Alternation Task. From the results of this, he considered that there was strong evidence for internal inhibitory ability, the active suppression of response following non-reinforcement, to emerge from around four years.

However, although the evidence from the results of the present study supports the hypotheses formulated from the aims of the study, and the review of literature, that dominant perseveration strategies are replaced by alternation strategies from around four years, the change does not appear to be adequately accounted for by Douglas' model. Some children clearly reverted to perseveration after, in a previous testing, alternation, although the general developmental trend was unidirectional.

Graphs plotted from means for age groups in all tasks illustrate this, and also the substantially higher levels of perseveration for the 3 year old sub-group than those for 5 year and 7 year old groups. There would appear from this, that an important cognitive advance is made from the fifth year in the ability to plan, reflect, and co-ordinate information, and which leads to the active reduction of error. However, the degree to which this cognitive competence is manifested in strategy use, seems also to be related to task, situational and social experience variables.

It is suggested from this that while the evidence supports a concept of qualitative change in inhibitory ability from about four years, that it undergoes further development. The factor identified from Factor Analysis carried out in this study, which was strongly age-related, and has been interpreted as emergent planning ability, gives some empirical support. Further, Schaffer (1974) and Luria (1973) have argued that maturation should be understood as progressive, in which new levels of CNS organisation become functional. it is within a concept of progressive reorganisation that both Douglas' (1972,1975,1976) and O'Keefe and Nadel's (1979) models of hippocampal function, and Luria's (1961,1973), concerning frontal lobe maturation, potentially clarify underlying processes of behavioural change. Alongside this, the evidence reviewed by Rosenthal and Allen (1978) is that developmental immaturity can be linked to a lack of uptake in the CNS of neurotransmitters which excite cholinergic neurons. Conel (1963,1967), too, has provided evidence of continuing structural changes in the hippocampus until at least 4 years, and of incomplete development in the frontal region at age 6. All these aspects might reasonably be thought to interact. Together, these contributions lead to the suggestion that the changes in child development reviewed, and the aspects empirically studied in this research, imply a further elaboration of cognitive functioning. Each aspect can then be seen as necessary, but not sufficient, to account for the developmental advances which have been argued as indicative of increasing planning ability in utilisation of cues and errors.

A unitary concept of inhibition is not, therefore, supported by the results of this study, and from this the process of strategy change may, too, be interpreted as elaboration. Flavell (1972,1977), conceptualised strategy evocation and use as addition, substitution, inclusion, or mediation. The evidence from this study does not support a mediation model, where strategy Y becomes independent of X, once established. Nor does it support a substitution model, in which X is abandoned when Y emerges. The evidence does, however, support addition, where Y provides an alternative to X as a means to a goal, but also a modification model, where a new strategy becomes stabilised and more readily evoked. The relationship between perseveration and alternation is suggestive of this. Although perseveration is replaced by a tendency to alternate, it remains within the child's repertoire and either strategy may be utilised, dependent upon the task and individual or situational variables. Combination strategies, resembling double alternation (Gellerman 1931, Goulet and Goodwin 1970) are suggested as indicative of inclusion of both early strategies and which form a larger unit (Flavell 1972, 1977). The appearance of complex patterns resembling double alternation (Gellerman 1931, Goulet and Goodwin 1970) from the quadratic trend found the Spontaneous Alternation task, and in the non-linear trends observed in 3 choice Discrimination Learning Task are suggestive of this.

It is concluded that, over the age range studied from 3 to 9 years, that there is evidence for elaboration of children's repertoire of strategies. The use of longitudinal design, with the repeated measurement of children, aged between 3 and 9 years, has illuminated this. The statistical techniques employed, together with qualitative data from individual curves, have supported the conclusion that children's dominant strategies change as a function of age. As strategies become available, they are used with increasing flexibility in active error reduction in problem-solving situations.

It is considered that the cross-sectional studies reviewed, have lacked explanatory power. Further cross-sectional work would not have contributed to understanding of the process of change within children at the age-levels studied.

However, the design of the present study has been able to illuminate these, and to indicate further lines of research from the work carried out. Educational implications have been drawn out. First, importance of the match between task demand and the child's dominant strategy has been discussed. Secondly, the potential of intervention to reduce educational disadvantage has been considered.

Two strands of literature, reviewed as sections I and II in Chapter 1, have been brought together through the nature of the design and the tasks used. Again, the longitudinal design has enabled a model of inhibitory function to be constructed from the apparently disparate studies of hippocampal and frontal lobe function. In these, the separate attribution of inhibition to localised areas have led to a 'naive parallelism'. Similarly, definitions of inhibition as internal have different implications. Douglas (1972,1975) considered internal inhibition to be primarily based on non-reinforcement, whereas Luria (1961,1973) and Pribram (1973) regarded the same construct as an integration of all sources of information.

The behavioural evidence gained in the present investigation supports a model whereby children from 4 years initially respond to non-reinforcement by alternating choice or response. Subsequently, the ability to integrate sources of information, and actively reduce error by planning action, appears to become elaborated.

It is concluded that this process is enabled by the development of a functional inhibitory system, in which both hippocampus and frontal lobes are implicated. Within this model, the development of availability and children's use of strategies between 3 and 9 years can be understood.

The investigation carried out for the present study is thus considered to have contributed to understanding of age-related strategy changes in children, and the underlying processes.

CHAPTER 6

Summary and Conclusions

The present study was designed to investigate the development of children's problem-solving strategies between the ages of 3 to 9 years. A small scale pilot study was carried out in 1979, to investigate the links suggested by the literature, that the maturation of central inhibitory processes underlies the emergence and use of adaptive strategies. From the results of the pilot work, the main study was constructed. Field work for this began in 1980, and was completed in 1983.

Six experimental tasks were administered to 96 children, following pre-tests of non-verbal intelligence (RCPM), language comprehension (Reynell Verbal Comprehension sub-scale), and conceptual tempo (MFF). The children were aged 3(N=32), 5(N=32), and 7 years(N=32) at the start of the study. The experimental task battery was administered on each of four separate testing occasions, of equal intervals, during a two year period for each child. The children were thus aged 5, 7 and 9 years on their fourth testing.

Twelve null hypotheses were formulated (Chapter 2) to test for differences between age-groups, and within children, in use of a perseveration or alternation strategy. The hypotheses were specified separately for each of the experimental tasks, Wisconsin Card Sorting Test, Spontaneous Alternation, the Oddity Problem, Two-Choice Discrimination Learning, Three-Choice Discrimination Learning and Attributes Task.

Significant differences, between age groups and within children, in the use of perseveration strategies were found from the two Four-Way Analysis of Variance carried out for each of the experimental tasks. Simple perseverations not only declined in an absolute sense but also as a proportion of error behaviour. This was confirmed by the linear trends found. As a corollary, with the decline in perseverations, an increase in alternation was found.

This last statement needs qualifying, since analysis of trends gave significant results for non-linear trends. First, this conclusion is drawn from the quadratic trend for testings on Spontaneous Alternation. This suggests that there is an age-related tendency to impose more complex patterns on unstructured data. Trends for testings showed that although a linear relationship fully described the strategy change within children, during the two year period of testing, some evidence of complex strategy use was shown from the interaction between age and testings, in Three-Choice Discrimination Learning. Secondly, the two reinforcement conditons showed interesting differences in the type of non-linear trend. Cubic trend was found in the 66% condition, but quadratic trend only on the 33% condition. The conclusion is drawn that, the 7 year old group of children's responses came to approximate more closely the demand of the task on the condition with the higher level of reinforcement, from imposition of pattern at the younger ages(66%). In the 33% condition, the lesser amount of reinforcement appears to have presented a more difficult problem for the extraction of the pattern, and, therefore, a greater likelihood of pattern imposition. This conclusion is further supported by comparison of means of total and perseverative errors made on the two conditions.

Further research, using systematic variation within, and between tasks, is suggested to illuminate further the effects of ambiguity on strategy utilisation.

It is concluded, from the rejection of all null hypotheses relating to differences between age groups and within children at the stated significance level of $p \leq .05$, that there is clear evidence demonstrating emergence of an age-related ability to plan behaviour in problem-solving tasks. This was also tested, in the null form, by Principal Components Analysis. The factor extracted for each of the four testings, was interpreted as an age-related planning ability. Varimax rotation indicated that this ability is manifested earlier in problems in which the child is able to impose a structure, ie. Spontaneous Alternation, which had no intrinsic pattern, than where synthesis of cues is demanded by the task.

The effects of practice, arising from the use of the repeated measures design, were investigated. The results indicated that practice effects were more pronounced at the 7 year old level (5 year olds at Testing 4 and 7 year olds at Testing 1), than for the comparative sample who were two years younger. The conclusion is drawn that practice is, itself, a function of age and that ability to utilise cues and errors in active error reduction thus increases. Support for this conclusion is further indicated by significant interactions between age and testing n all tasks except the Wisconsin Card Sorting Test.

Practice effects were not predicted from the literature on the Spontaneous Alternation Task, but 3 year olds at Testing 4 perseverated less than 5 year olds at Testing 1. The conclusion is drawn, and which is consistent with the literature, that the higher alternation rate on the fourth testing (3 year olds) represented a novelty seeking in the maintenance of alertness. It is further concluded that this group had more confidence in testing situations and that this would increase exploratory behaviour.

Differences within tasks were found according to condition experienced by the children, and those relating to the Three-Choice Discrimination Learning Task have been summarised. The Two-Choice Discrimination Learning Task gave results from Binomial Tests carried out between reversal and non-reversal conditions on this task. The children in this study did not find it more difficult to make a reversal, contrary to similar studies reported in the literature. Instead, more errors were made on the first condition experienced, irrespective of whether a reversal was required, although the youngest children found both conditions more difficult than did the older age groups. It is concluded that success on this task was more closely related to passive, rather than active, inferential ability (Bryant 1974). With two choices only, and

100% reinforcement for the correct choice, the demand for planning ability by the children was low. Their increased success on the second condition from the first, is interpreted as evidence of learning what was required by the task.

A different pattern, and one which leads to the conclusion that the Two-Choice Discrimination Learning Task was a poor discriminator of age-related planning ability, was shown by within-task analysis of Wisconsin Card Sorting Test. Total errors, and also perseveration errors, rose with successive categories completed. This was most noticeable in the second category, sorting to shape, following sorting to colour. The first reversal appeared to be more difficult than the later shift to sorting for number, as evidenced by the means of total and perseveration errors by the children solving three categories.

Suggestions have been made for further research following this interesting result, to investigate whether developmentally, number becomes salient; analogous to the earlier colour-form shift (White 1965). Whether this is due to the effects of entering school, and the emphasis placed in the curriculum on numeracy, is a question for which the present investigation is not designed. Consistent with the literature, a repeated order of category sorting was used.

From the analyses of each task and comparison of differences shown between tasks it is concluded that children's planning ability is related to the cognitive demand posed by a task.

Further subsidiary null hypotheses were tested, concerning difference between the sexes and S.E.S. groups in use of perseverative strategies. The results are summarised separately, and also together, from the interactions found.

Sex differences were found on Spontaneous Alternation and on Three-Choice Discrimination Learning (66%). These are consistent with findings in the literature, that girls have an early developmental advantage on this type of task. It is concluded that, if Spontaneous Alternation behaviour does reflect, as is suggested, the emergence of inhibitory function, then this takes place earlier in girls than boys. However, judged by the earlier emergence of more complex strategy patterns, used by boys, the relative positions of the sexes are reversing from 7 years, again, consistent with the literature.

Differences between socio-economic status groups showed advantages in active error reduction behaviour for the upper S.E.S. group. The Wisconsin Card Sorting Test results most clearly showed this as a significant main effect from the ANOVAS. Interaction effects of S.E.S. were apparent on all experimental tasks, except the Oddity Problem, and Two-Choice Discrimination Learning Task.

While the conclusion is drawn that the effects of S.E.S. were most influential at the pre-school level (3 year old group), the interactions with sex, age and testings at other ages preclude the drawing of further conclusions.

It is, however, concluded that the apparent narrowing of the gap between children from the two socio-economic groups provides encouragement for the educative process, and for intervention into disadvantage. This conclusion is supported by the literature that early disadvantage in reading and language is not necessarily irreversible (Beveridge & Jerrams 1981, Wedge and Essen 1982, Tizard et al 1982).

Language change in problem-solving was investigated in a mainly qualitative form. At the earliest age level studied in the present investigation, the spontaneous comments of children on the Wisconsin Card Sorting Test implied, as Luria (1961) has suggested, a dissociation between language and the organisation of behaviour. From elicited comments after completion of tasks, the children's explanations of their problem-solving behaviour reflected a growing ability to represent behaviour by means of language. This conclusion is supported by the quantitative analysis of levels of solution on the Oddity Problem, which indicated an age-related ability to give a verbal justification of the Oddity concept.

Individual curves of performance on the Wisconsin Card Sorting Test and on Spontaneous Alternation revealed differences between and within children. Curve types were identified by grouping related individual curves. Within a curve type individual differences in rate of development were shown. The conclusion is drawn from the variation between and within curves that there are identifiably different clusters of individual approaches to problems. Nevertheless, prediction of individual development appears to be an uncertain matter. The correlations between pre-tests and experimental tasks, which were only moderately significant, are suggested as further support of this point.

The results of this study have provided evidence that an inhibitory ability becomes available to children from their fifth year. This is manifested by the onset of alternation and increased ability to use cues and errors in active error reduction. It is concluded that availability is not the same as use. Task variables clearly influence the use which children are able to make of their developing repertoire of strategies. It is concluded that an inhibitory ability is a necessary but not sufficient, condition for planning action in active error reduction. The review of literature of absence of hippocampal function following lesion, or in immature animals, has provided correlational support that there may be increased inhibitory activity in the hippocampus at around four years of age in children. The qualitatively different performance of the 3 year old group from that of the 5 and 7 year old groups, would appear to support this conclusion. Further support is provided by the child developmental literature. (e.g. Douglas 1972, 1975). However, the variations within children and between tasks, together with the literature concerning development, and deficit following lesion, of the frontal lobes, leads to the further conclusion that a unitary model of inhibition cannot be sustained. The temporal stacking model suggested by White (1965) in which lower level strategies may be disinhibited, is considered to have utility. It is concluded, from the behavioural evidence gained in this study, that a new functional system is developing. The parallel is drawn with the suggestion from Luria (1973) and Schaffer (1974) that brain organisation, too, is to be defined in terms of systems.

Changes in the availability and use of strategies have been observed from the results of this longitudinal study. Perseveration appears to be retained in the child's repertoire after alternation appears, and there is evidence of further elaboration of strategies. This major finding is considered to support the conclusion that inhibitory ability itself undergoes further development, and is differentially utilised.

Utilisation of strategies has been shown to be task and situation specific as well as age-related. It is concluded that the results indicate addition of strategies and inclusion of these in elaborated form (Flavell 1972,1977).

The conclusions have thus been drawn from the behavioural evidence that prior to about 4 years of age, children's dominant choice or response is perseveration. Subsequently, children initially respond to non-reinforcement by alternation of choice or response. Following this, the ability to integrate sources of information and actively reduce error by the planning of action, appears to become elaborated.

The results, together with the child development literature, reviewed as Section I, Chapter 1, and the disparate studies of hippocampal and frontal lobe lesion and development, Section II, have supported a model of developing inhibitory functional system. In this, both hippocampus and frontal lobes are implicated, rather than the 'naive parallelism' (Gale 1980) in which inhibitory function has been attributed separately to the hippocampus and the frontal lobes (Douglas 1972,1975; Luria 1973; Pribram 1973).

These conclusions have been enabled by the longitudinal design used in the present study. The combination of longitudinal research with the repeated use of six experimental tasks has illuminated development and change in the availability and use of children's problem solving strategies between 3 and 9 years. Other alternatives of research design are considered to lack the explanatory power of the present design.

From the work carried out, educational implications for intervention into disadvantage, and quality of learning experiences have been discussed. Additionally, the need for continuing identification procedures for children with special educational needs has been considered.

Directions for future research, arising from this study, have been discussed. These include the investigation of the relationship between task demand to strategy use, and the hypothesis that number becomes a salient dimension during the school years.

It is concluded, finally, that the design and work carried out for this study has contributed to basic research. The model of development of a functional inhibitory system provides a means of understanding the underlying processes of development and use of strategies by children between 3 and 9 years which was the aim of the study.

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APPENDICES

APPENDIX 1

PILOT STUDY

PILOT STUDY

A small scale pilot study was carried out in 1979 to assess whether there was initial support for the hypotheses to be tested in the main study, and for the purpose of design and selection of tasks to be included in the main study test battery. Eight tasks were used in the study and are listed:

1. Binary pattern making tasks - Frith (1970b)
2. Spontaneous alternation - Clayfield (1976)
3. Varying probability - Frith (1970b)
4. Oddity problem - Lunzer (1968)
5. Two-choice discrimination learning - Lynn & Compton(1966)
6. Three-choice discrimination learning
7. Delayed-response - spatial and non spatial conditions
8. Memory game

A small sample of children were considered sufficient for the purposes of the pilot study. It consisted of 16 children aged 3.6 - 4.6 (N=8), and 6.6 - 7.6 (N=8) drawn from a Primary school serving a New Town population in Hertfordshire. (See Appendix 6). All the children were from social class 3 (W) and (M) according to the Registrar General's classification (1970). The 3-4 year old sample attended either part or full time in the nursery class of the school, and the 6-7 year olds attended the school's vertically grouped infant classes. They were all considered by the school to be without physical or learning disabilities. A familiarisation process was carried out by the writer, who spent time in each classroom, especially in the nursery, prior to commencement of testing. This was done individually on 3 occasions for each child in a library area adjacent to the classrooms, although one 3 year old boy was tested on the first occasion in the nursery classroom, since he resisted leaving his familiar scene. Subsequently he seemed happy to leave his classroom.

Testing took place over a period of 5 weeks, and included video-taping a sample across all tasks, with each child, for retrospective review, and, in particular, a Memory Game which, although not retained in the main study task battery, is discussed later for its interest in the study. Similarly, the Delayed-Response task, which was not retained is discussed, following consideration of the tasks subsequently used in the main study.

Tasks retained in main study

The tasks retained following the pilot study for inclusion in the main experiment were Spontaneous Alternation, Two Choice Visual Discrimination Learning and the Oddity Problem. These tasks, except for Spontaneous Alternation, which had had extensive previous use (Clayfield 1976), were subjected to further modification, and piloting, prior to commencement of the main study. Their final form is fully described in Chapter 3, but some relevant results and points of interest are considered briefly.

Oddity Problem

Data was categorised as learnt or not learnt the Oddity Problem by each of the two age-groups, within 36 trials. This has been analysed by the Fisher Exact probability test.

Table 84 Oddity Problem - 2x2 Contingency Table - Fisher Exact Probability Test

	3.6-4.6 years	6.6-7.6 years
Learnt problem	0	4
Not learnt problem	8	4

Since the critical value from the table exceeds the observed value, the null hypothesis (there is no significant difference between age groups of children learning the problem) is rejected ($p < .05$).

In this task, 36 trials (6 problems of 6 trials each)were used, whereas in the study reported by Lunzer (1968) 120 trials (20 problems of 6 trials each) were administered. The difference in number of trials is suggested as explanatory of the greater success by young children in solving the Oddity Problem which was reported by Lunzer.

Two features from the task merit attention. First,the persistent perseverators chose predominantly the same card in most of the problems, and secondly, older children had, in several cases, to be dissuaded from treating the two identical colours as a single unit, and responding as though to a 2 choice problem. These children stated a choice as 'green' etc. and were then requested to point to the choic . It is interesting to speculate that in some way, such children restructured the task,and through language, simplified the task, into an either/or situation.

The task, with a modification to increase trials to a maximum of 60, was included in the experimental task battery, since it appears to have construct validity in relation to the aims of the study, ie. the investigation into developmental trends in the utilisation of cues and errors,and a corresponding adaptation of the strategy used.

Table 85 Mean errors made on each of two conditions for each age level on Two Choice Discrimination Learning

	Condition a (No Reversal) 1st choice correct Trials Total = 10	Condition b (Reversal) 1st choice incorrect. Trials Total = 10
3.6-3.11	x = 4.4 s.d 1.14	x = 2.4 s.d 1.14
4.0-4.6	x = 3.66 s.d 1.15	x - 1.66 s.d 1.52
6.6-6.11	x = 3.5 s.d 1.29	x = .75 s.d .957
7.0-7.6	x = 3.25 s.d 1.25	x = 0 s.d 0

Table 85 shows that more errors were made by 3 and 4 year olds on both conditions than 6 and 7 year olds. The younger age groups f children used trial and error learning less than old children in Two Ch ice Visual Discrimination Learning,and made more errors particularly when a r versal was demanded for solution.However, contrary to expectation, and review of the literature, mean errors at each age level on the non-reversal condition were higher than for the reversal condition. It is suggested that this result may have been an artefact of the constant order of presentation, and in the main study, a counter-balanced procedure is used.

Comparison of Spontaneous Alternation with Varying Probability and Spontaneous Binary Pattern Making Task.

Of these three tasks, only Spontaneous Alternation has been retained for use in the main study. Results were consistent with those obtained in extensive previous use (Clayfield 1976) and the results from the pilot study are discussed only in comparison to two tasks not retained. These were Spontaneous Binary Pattern Making Task (Frith 1970a) and a Varying Probability Task (Frith 1970b) and procedures for these are given. Full details of administration of the Spontaneous Alternation Task are given in Chapter 3.

Spontaneous Binary Pattern Making (Frith 1970)

Materials - white board with raised ledge for guidance of pattern making, and 4cm square cards - 11 different colour sets, from which the subject chooses 2 colour sets. After choosing which colours are to be used, the subject is instructed to 'make a pretty row'. The length of the board permits a total of 15 cards to be placed. The pattern made by the subject is recorded to allow analysis of perseverations and alternations of card colours.

Varying Probability (Frith 1970)

Materials - 15 orange cards each 4 cm square, and 15 maroon cards each 4 cm square. The procedure is then identical with that of Spontaneous Alternation, but after each guess, the cards are turned face upwards to provide information about the correctness of the guess. Recording of each guess as Win or Lose is made on a prepared sheet, and shifts are noted as 's'.

For purposes of comparison between these 3 tasks a proportion of perseverations of total trials was obtained for each subject in each task since the number of trials was not equal in all 3 tasks. Arc-Sine transformations were then derived. (See Table 86).

Table 86 Comparison of Mean Proportion of Perseverations to Total Trials(Arc-Sine) on Spontaneous Binary Pattern Making (Task1),Spontaneous Alternation(Task2) and Varying Probability (Task3).

	Task 1	Task 2	Task 3
3.6-3.11(N=5)	x = 68.25 sd 28.34	66.53 37.60	54.97 20.54
4.0-4.6 (N=3)	x = 55.59 sd 36.88	16.67 28.87	33.60 7.686
6.6-1.11(N=4)	x = 38.41 sd 28.47	28.94 19.96	38.96 5.44
7.0-7.6 (N=4)	x = 3.23 sd 18.37	47.64 14.22	47.05 7.02

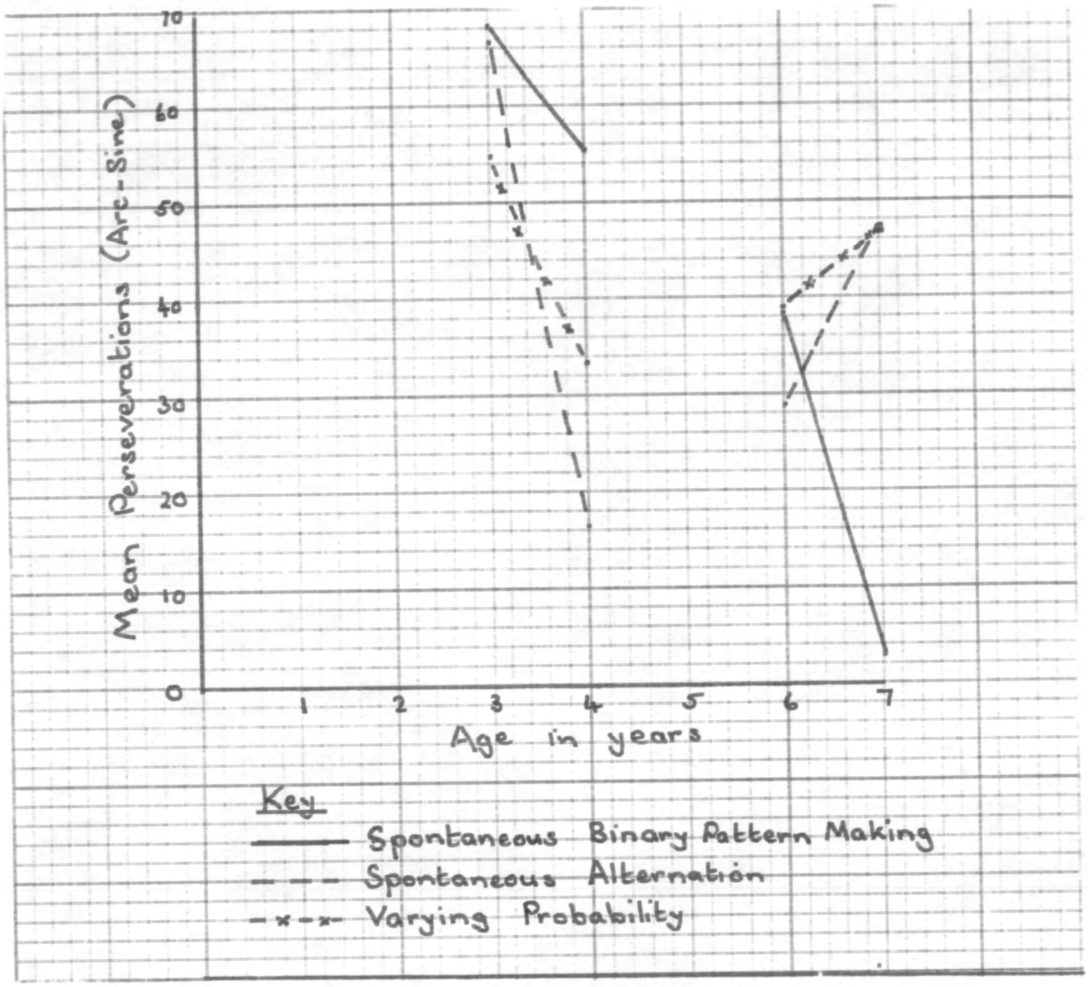
Inspection of the means indicate age and some task related, differences of proportions of perseverations to total trials.

Perseveration as a feature of age and/or task

The review of the literature; together with the tentative support gained from this pilot study, suggests that perseverative strategies are dominant in children younger than 4 years, and that alternation strategies are more likely to be used on children older than 4 years. This would appear to be the case in relatively unstructured tasks, in which children appear to impose their own pattern on the data (Frith 1970). Varying Probability (Task 3) is a direct replication of Frith's task (1970) and in her study of autistic, normal and sub-normal children, she suggested that seeing the card had no effect on perseveration or alternation behaviour, and served only to reduce the monotony of the task. However, from the graphical presentation of the means, (Fig31) it can be seen that although the direction of the data is the same for Tasks 2 and 3, there are differences in mean number of perseveration for all except the 7 year old group.

From Figure 31 it is suggested that strategy use is differentially affected by the task, although the nature of the relationship is unclear.

Figure 31 Comparison of Mean Proportion of Perseverations to Total Trials (Arc-Sine) on Spontaneous Binary Pattern Making (Task 1), Spontaneous Alternation(Task 2) and Varying Probability (Task 3).



One aim of the pilot study, as a preliminary to formulating the hypotheses for the main study, was to gauge whether the use of perseveration or alternation strategies is influenced by the task, and there would appear to be evidence for this.

Further aspects of relevance to the investigation

From the literature reviewed for the present investigation, it seemed likely that children of 6 and 7 years old would make more double alternation choices in a two choice task than would 3 and 4 year old children. Double alternations are defined as alternation following 2 responses which repeat the same choice. In the simplest form, it can be represented as aabbaabb, whereas single alternation, again at the simplest level, would be abab. Such double alternations would appear to account for the typical curve shown in the literature in which from about 4 years perseveration abruptly declines in a 2 choice task, and then appears to be re-instated to a much lesser degree around 7 years, for what have been argued to be different reasons (Weir 1964). The phenomenon yields a U shaped curve, and interpretation of a likely qualitative difference but quantifiably similar scores is a difficulty for the researcher (Wohlwill 1973). This is considered further in Chapter 5. In Binary Pattern Making (Task 1) and on Spontaneous Alternation (Task 2), visual inspection of the means of double alternations for the 2 tasks show differences between younger and older children.

Table 87 Double Alternations made on Binary Pattern Making Task and Spontaneous Alternation - Combined.

3.6-3.11	-	double alternations $\bar{x}$ = 4
4.0-4.6	-	double alternations $\bar{x}$ = 5.6
6.6-7.0	-	double alternations $\bar{x}$ = 9.5
7.0-7.6	-	double alternations $\bar{x}$ = 8.25

Since the total sample was only 16 subjects, with unequal numbers in age groups, no further analysis was carried out. The means are regarded as indicative only of age-related differences, and of interest to the aims of the main study.

Delayed Response Task

This task had 2 conditions, one a spatial version, and the other, a non-spatial. The materials were 2 identical wooden boxes placed one behind the other in the spatial version, identical coloured cards were placed on top of each box, and in the non-spatial, 2 differently coloured cards were used. In each condition a marble was placed in one of the boxes in counter-balanced order across the subjects. Simultaneously, the statement was made "I am going to hide a marble in this box". The boxes were then covered by cardboard, whilst the subject was engaged in "helping me sort out these cards" (a pack used in Task 2). After 5 minutes, the cover was removed and the question was asked "which box has the marble in it?" This task was analysed by Fisher-Exact Probability Test, and results are shown in Table 88.

Table 88 Delayed Response Task 2x2 Contingency Table - Fisher Exact Probability Test.

	Learnt	Not Learnt
3-4 years	3	5
6-7 years	8	0

Since the observed value is less than the critical value from the table, the null hypothesis of no significant difference between age groups in learning the Delayed Response Task is rejected ($p < .05$).

The delayed response task was not considered suitable for inclusion in the experimental test battery, for the main study, since this was to be longitudinal in nature, and utilising a repeated measures design. It was considered that the task was unlikely to reveal developmental change in any but the younger children, and that ceiling effects for older children would preclude the drawing of meaningful conclusions. However, a point of interest is that the 3 younger children who succeeded in locating the box in the delayed response task, did so on the non-spatial condition. In view of the very small sub-sample, no further tests of significance are applicable, but it is suggested that the younger children, for success, needed more redundant information of colours as well as position. The testing of this hypothesis would need to be undertaken with a much larger sample than has been used in this pilot study. There are also methodological problems to be resolved. Young infants have been found to be successful in locating a hidden object (Butterworth and Jarrett 1982).

The Memory Game

The second task of interst, the Memory Game, is conceptually related to the delayed response task. It used a 'Pelmanism' approach, similar to games used in and out of school, and had thus some educational implications. The genuine game quality made for naturalistic, and further observation, of how far perseverative strategies are dominant in younger, but not older, children.

Materials

16 cards were used, each 4cm square, comprising 8 pairs of colours. These were laid face up in front of the subject in

predetermined order as

ochre	green	blue	purple
yellow	red	black	orange
purple	blue	ochre	black
red	orange	yellow	green

The subject was allowed to look at the card, and a check was made that, subjects could match the colours. The subject was then told "I'm going to turn the cards over so you can't see them". After this was completed, the subject was asked to "Turn over 2 cards. Do they match?"

If yes, the pair was then removed from the display, but if not, the cards were replaced face downwards, and the game continued with the same instruction given. The task continued until all pairs had been matched. A hand-operated video camera was used to record the subject's moves, with the intention of using the videotape to give data for statistical analysis. This was not possible in the event, as a fault developed with the camera, and some recordings were lost. However, a diagram (Figure 32)was constructed from the successful recordings of a boy (3.9 years) and a girl (6.8 years), which illustrates the responses typical of older and younger children.

The task, although of considerable interest to the aims of the main study, was not retained because of the practical difficulties of single-handed administration and scoring.

Figure 32 Pairs of colour choices made in Memory Game

Katie 6-8years □

Russell 3-9years

Numbers indicate order of choices

Successful pairings

Katie	Russell
3	14
4	18
5	29
7	33
8	39
10	42
12	44
13	45

Purple 1 25 $\boxed{1}$ 4 27 $\boxed{2}$ 7 30 $\boxed{6}$ 10 38 $\boxed{9}$ 16 39 $\boxed{11}$ 20 $\boxed{13}$ 21 24	Orange 2 30 $\boxed{9}$ 7 34 $\boxed{10}$ 17 40 19 43 20 44 24 25	Black 2 $\boxed{5}$ 5 17 18	Green 3 $\boxed{4}$ 10 19 21 27 28 33
Blue 1 $\boxed{8}$ 4 31 32 41 42	Black 15 $\boxed{5}$ 16 18	Ochre 5 45 $\boxed{7}$ 15 31 34 35 40 43	Yellow 3 $\boxed{11}$ 28 $\boxed{12}$ 29
Green 9 $\boxed{4}$ 22 32 33	Red 12 $\boxed{2}$ 14 $\boxed{3}$	Blue 6 $\boxed{8}$ 12 35 36 42	Orange 13 $\boxed{1}$ 22 $\boxed{10}$ 36 41 44
Ochre 8 45 $\boxed{6}$ 9 $\boxed{7}$ 11 23 26 37 38	Yellow 8 $\boxed{12}$ 11 23 29	Purple 6 $\boxed{13}$ 26 37 39	Red 13 $\boxed{3}$ 14

Child

The diagram illustrates not only that Russell made far more pair choices than Katie's, (45 pairs compared to 13 pairs), but also that his strategy tended to be a perseverative one, eg. consecutive choices of purple (20 21 25 25/38 39). This would support the hypothesis that perseveration, as a primitive strategy, does not enable the active reduction of error, that is necessary condition of successful problem-solving.

The eighth task, Three-Choice Discrimination Learning, was discarded from the pilot study because of practical problems of administration. Instead the decision was made to use, in the main study, the task originally described by Stevenson and Zigler (1958), with modifications to the form of instructions.

APPENDIX 2

Experimental Design - Main Study

C - Treatment Order - counterbalanced across subjects and test occasions

A	B	E	c1	c2	c3	c4
Age	Sex	SES	D - Testings d1	d2	d3	d4
a1	b1	e1	S1 - 8	S1 - 8	S1 - 8	S1 - 8
3		e2	S17 - 24	S17 - 24	S17 - 24	S17 - 24
years	b2	e1	S9 - 16	S9 - 16	S9 - 16	S9 - 16
		e2	S25 - 32	S25 - 32	S25 32	S25 - 32
a2	b1	e1	S33 - 40	S33 - 40	S33 - 40	S33 - 40
5		e2	S49 - 56	S49 - 56	S49 - 56	S49 - 56
years	b2	e1	S41 - 48	S41 - 48	S41 - 48	S41 - 48
		e2	S56 - 64	S56 - 64	S56 - 64	S56 - 64
a3	b1	e1	S65 - 72	S65 - 72	S65 - 72	S65 - 72
7		e2	S81 - 88	S81 - 88	S81 - 88	S81 - 88
years	b2	e1	S73 - 80	S73 - 80	S73 - 80	S73 - 80
		e2	S89 - 96	S89 - 96	S89 - 96	S89 - 96

The design is mixed, with 3 between factors (Age, Sex, S.E.S.) and 1 within factor (Testings)

Experimental Design - Main Study

APPENDIX 3

Experimental task order of administration
for each group of children and for each
testing occasion

Experimental task order of administration for each group of children and for each testing occasion

Group	Testing 1	Testing 2	Testing 3	Testing 4
A	1 4 6 3 5 2	1 6 5 2 3 4	2 5 1 4 3 6	5 1 4 2 6 3
B	4 3 2 6 1 5	3 2 6 5 4 1	6 5 1 2 3 4	2 4 1 5 3 6
C	3 5 6 4 2 1	4 3 6 5 2 1	5 2 3 6 1 4	1 2 6 3 5 4
D	6 4 3 5 2 1	1 2 6 4 3 5	3 4 6 1 2 5	5 4 3 1 2 6
E	4 5 6 3 1 2	5 4 3 1 2 6	2 5 6 3 1 4	6 1 3 5 2 4
F	2 5 1 4 3 6	4 2 5 1 6 3	1 2 4 3 5 6	3 2 4 5 1 6
G	1 3 2 4 5 6	5 6 2 3 4 1	4 1 3 2 6 5	2 6 3 4 1 5
H	3 4 6 1 2 5	1 2 6 5 3 4	6 4 3 1 5 2	4 3 6 1 5 2
I	3 1 6 2 5 4	1 4 6 3 5 2	5 6 1 2 3 4	6 5 1 2 3 4
J	5 2 6 1 3 4	3 1 2 6 5 4	1 5 6 4 3 2	1 5 2 4 6 3
K	5 4 3 1 6 2	3 2 5 4 1 6	4 6 2 3 5 1	4 1 6 2 5 3
L	2 6 5 3 4 1	3 4 5 2 1 6	6 3 1 4 2 5	3 6 5 2 4 1
M	4 3 2 1 5 6	6 3 2 5 1 4	1 3 2 4 5 6	6 3 2 5 1 4
N	2 5 6 3 1 4	3 4 1 2 6 5	1 4 6 2 5 3	1 3 6 4 2 5
O	5 6 1 2 3 4	5 1 4 3 6 2	4 3 2 1 6 5	2 4 3 1 5 6
P	1 5 6 4 3 2	2 3 4 1 6 5	2 1 4 6 3 5	4 2 6 5 3 1

Note - 1. Children included in each group are listed on next page.

2. Key to Task names represented by numbers is given on next page.

Children allocated to each order group

Group	Numbers
A	1, 17, 33, 49, 65, 81
B	2, 18, 34, 50, 66, 82
C	3, 19. 35, 51, 67, 83
D	4, 20, 36, 52, 68, 84
E	5, 21, 37, 53, 69, 85
F	6, 22, 38, 54, 70, 86
G	7, 23, 39, 55, 71, 87
H	8, 24, 40, 56, 72, 88
I	9, 25, 41, 57, 73, 89
J	10, 26, 42, 58, 74, 90
K	11, 27, 43, 59, 75, 91
L	12, 28, 44, 60, 77, 92
M	13, 29, 45, 61, 78, 93
N	14, 30, 46, 62, 79, 94
O	15, 31, 47, 63, 80, 95
P	16, 32, 48, 64, 81, 96

Key to task numbers

1 = Wisconsin Card Sorting Test

2 = Spontaneous Alternation

3 = The Oddity Problem

4 = Two-choice Discrimination Learning Task

5 = Three-choice Discrimination Learning Task

6 = The Attributes Task

APPENDIX 4

Samples of completed scoring sheets from experimental tasks

Spontaneous Alternation

S. 13 GL 8.2.77 | S 42 GL 10.6.75 | S 84 BU 31.7.73

Testing 1

Test 1	R	B
1		/
2		/
3		/
4		/
5		/
6		/
7		/
8		/
9		/
10	/	
11	/	
12	/	
13		/
14		/
15	/	
16	/	
17		/
18		/
19		/
20		/
21		/
22		/
23		/
24		/
25		/
26		/
27		/
28		/
29		/
30	/	

24 P

Testing 3

Test 1	R	B
1	/	
2		/
3	/	
4		/
5	/	
6		/
7	/	
8		/
9	/	
0		/
1	/	
2		/
3	/	
4		/
5	/	
6		/
7	/	
8		/
9	/	
0		/
1	/	
2		/
3	/	
4		/
5	/	
6		/
7	/	
18		/
19	/	
30		/

0 P

Testing 4

Test 1	R	B
1		/
2	/	
3		/
4		/
5		/
6	/	
7		/
8		/
9	/	
10	/	
11		/
12	/	
13		/
14		/
15	/	
16	/	
17	/	
18		/
19		/
20	/	
21	/	
22	/	
23		/
24		/
25	/	
26		/
27	/	
28		/
29		/
30	/	

12 P

S. no 13 GLSES D of B 8.2.77 344.

WCST Testing I

△ * + o △ * + o △ * + o

Trial	Response	Trial	Response	Trial	Response
1	4Y o ✓	29	4B + ✓	57	1R o c
2	1Y * ✓	30	3B * ✓	58	1R + c
3	4R △ ✓	31	2Y + ✓	59	2B + ✓
4	4Y o ✓	32	1G * ✓	60	2B o ✓
5	3R o ✓	33	3Y * c	61	1R △ ✓
6	2G o ✓	34	1B * c	62	3Y △ c
7	3B + ✓	35	2R * ✓	63	4G o R
8	2B *	36	1R * c	64	1G △ c
9	4Y △ ✓	37	2Y △ c		
10	1Y + ✓	38	1Y △ c		
11	4Y * c	39	3B △ c		
12	3R △ ✓	40	1Y o c		
13	3G △ c	41	1B + ✓		
14	2G * ✓	42	3Y o ✓		
15	3G + c	43	1B △ ✓		
16	2R △ ✓	44	2Y o c		
17	3G + c	45	4B * c		
18	4Y + ✓	46	3G o R		
19	4B △ c	47	4G △ c		
20	3B o ✓	48	2G △ c		
21	4G * ✓	49	2B △ ✓		
22	3R * c	50	3R + c		
23	3G * ✓	51	2R o c		
24	1B o ✓	52	2G + c		
25	4B o ✓	53	2Y * c		
26	3Y + ✓	54	2R + c		
27	4R * c	55	1G + c		
28	[illegible]	56	1G [illegible]		

33 errors

31 correct

1 category

1) E = 0

2) E = 33

11 A

22 P

S.no 13 GLSES D of B 8.2.77

Oddity Problem Testing 1

	1		31		61	
	2		32		62	
1	3	6	33	11	63	
	4		34		64	
	5		35		65	
	6		36		66	
	7		37		67	
	8		38		68	
2	9	7	39	12	69	
	10		40		70	
	11		41		71	
	12		42		72	
	13		43		73	
	14		44		74	
	15	8	45	13	75	
	16		46		76	
	17		47		77	
	18		48		78	
	19		49		79	14 E
	20		50		80	9 A
	21	9	51	14	81	5 P
	22		52		82	
	23		53		83	
	24		54		84	
	25		55		85	
	26		56		86	
	27	10	57	15	87	
	28		58		88	
	29		59		89	
	30		60		90	

S. no 13 GLSES D of B 8. 2. 77

2 choice Discrimination Learning Testing 1

Condition order 1 = a/b 2 = a/b

Condition (a) - no reversal

1

Trial		
Pre.	✓	
1		✓
2		✓
3	✓	
4	✓	
5	✓	
6	✓	
7	✓	
8	✓	
9	✓	
10	✓	
11	✓	
12	✓	
13	✓	
14	✓	
15	✓	
16	✓	
17	✓	
18	✓	
19	✓	
20	✓	

Errors = 2

1 A
1 P

Σ = 6

2 A
4 P.

Condition (b) - reversa

2

Trial		
Pre	✓	
1	✓	
2	✓	
3	✓	
4		✓
5		✓
6		✓
7		✓
8		✓
9		✓
10		✓
11		✓
12		✓
13		✓
14		✓
15		✓
16		✓
17	✓	✓
18		✓
19		✓
20		✓

Errors = 4

1 A
3 P

S. no-13 G LSES D of B 8. 2. 77

3 choice Discrimination Testing 1

66% 33% Reinforcement

Trial	R	M	L
1	✓		
2	✓		
3	✓		
4	✓		
5	✓		
6	✓		
7	✓		
8	✓	1	
9	✓		
10	✓		
11	✓		
12	✓		
13	✓		
14	✓		
15	✓		
16		2✓	
17	✓		
18	✓		
19	✓		
20		3	
21			✓
22			✓
23			✓
24		4	
25	✓		
26	✓		
27	✓		
28	✓		
29	✓		
30			

Trial	R	M	L
31	✓		
32	✓		
33	✓		
34	✓		
35	✓		
36	✓		
37	✓		
38	✓		
39	✓		
40		5	
41			✓
42			✓
43			✓
44	✓		
45	✓		
46	✓		
47	✓		
48	✓		
49	✓		
50	✓		
51	✓		
52		6	
53		7	
54	✓		
55	✓		
56	✓		
57	✓		
58	✓		
59	✓		
60	✓		

Trial	R	M	
61	✓		
62		8✓	
63			✓
64	✓		
65	✓		
66	✓		
67			✓
68			✓
69			✓
70			✓
71			✓
72		9	
73	✓		
74	✓		
75	✓		
76	✓		
77		10✓	
78	✓		
79	✓		
80	✓		

70 E
51 P
12 A

S. no 13 GLSES D of B 8.2.77

Attributes Testing 1

Block 1

Trial 1, 2, 3, 4, 5, 6, 7, 8

Block 2

9, 10, 11, 12 (0), 13, 14, 15, 16

Block 3

17, 18, 19, 20, 21, 22, 23, 24

25, 26, 27, 28, 29, 30, 31, 32

Block 5

33, 34, 35, 36, 37, 38, 39, 40

Block 6

BUSE

S.no. 84

Wisconsin Ca[rd] Sorting Test

D of B 31.7.

Testing 4

△ ☆ + o — △ * + o — △ * + o

Trial	Response	Trial	Response	Trial	Response
1	1R +S	29	1R */	57	2R 0/
2	3G 0/	30	4G +/	58	2G △/
3	3G +/	31	1R 0/	59	4B */
4	3R +/	32	3Y △/	60	4Y */
5	3B 0/	33	1G +/	61	4Y +/
6	2G +/	34	3Y +/	62	1G 0/
7	3Y 0/	35	3R △ sc	63	1Y +/
8	4Y 0/	36	1B 0 sc	64	3R 0/
9	3B △/	37	4G * sc		
10	4B +/	38	4B 0/		
11	2Y △/	39	4G △ c		
12	3B * c	40	2B 0 sc		
13	2Y 0/	41	4R 0 c		
14	1Y 0/	42	2G */		
15	2Y 0/	43	4R + s		
16	2B +/	44	2B △ s		
17	1B +/	45	1G △ c		
18	1B */	46	2Y + sc		
19	4R */	47	1B △/		
20	2B */	48	2Y */		
21	1Y */	49	1R △/		
22	3B + iw	50	4Y 0/		
23	4B △ c	51	4R △ sc		
24	3G △/	52	4Y △/		
25	1G */	53	2R △/		
26	1Y △/	54	3G */		
27	3Y */	55	3R * s		
28	2R */	56	2R + s		

1) 1 / 11

2) 3 / 28 — 1A 2P

3) 13 / 31 — 7A 6P

S. no 84   B USES   D of B   31.7.73

Oddity Problem   Testing 4

Problem	Trial				Problem	Trial				Problem	Trial				
	1		x /			31			√		61	x			
	2	/				32					62				
1	3		/		6	33				11	63				1
	4		/			34					64				
	5		/			35					65				
	6		/			36					66				
	7	x	/			37		/			67			x	
	8	/				38					68				
2	9	/			7	39				12	69				17
	10	/				40					70				
	11	/				41					71				
	12	/				42					72				
	13			/		43	x /				73		x		
	14			/		44					74				
3	15			/	8	45				13	75				18
	16			/		46					76				
	17			/		47					77				
	18			/		48					78				
	19		/			49 VJ			x /		79	x			
	20					50 Sck E purple					80				
4	21				9	51				14	81				1
	22					52		x			82				
	23					53					83				
	24					54					84				
	25	x /				55		x			85			x	
	26					56					86				
5	27				10	57				15	87				2
	28					58					88				
	29					59					89				
	30					60					90				

S.no 84 B USES D of B 31.7.73

2 choice Discrimination Learning Testing 4

Condition order 1 = a/b 2 = a/b

Condition (a) - no reversal

2

Trial	Ochre	D. Blue
Pre.	/	
1	/	
2	/	
3	/	
4		/
5	/	
6	/	
7	/	
8	/	
9	/	
10	/	
11	/	
12	/	
13	/	
14	/	
15	/	
16	/	
17	/	
18	/	
19	/	
20	/	

1E
1A

3A
1P
= 4E

Condition (b) - revers

1

Trial	Purple	Grey
Pre		/
1		/
2	/	
3		/
4	/	
5	/	
6		/
7	/	
8	/	
9	/	
10	/	
11	/	
12	/	
13	/	
14	/	
15	/	
16	/	
17	/	
18	/	
19	/	
20	/	

3E
1P
2A

S. nô 84 B USES D of B 31:7:73 352

3 choice Discrimination Learning

66 % / 33 % reinforcement

Trial	R	M	L	Trial	R	M	L	Trial	R	M	L
1			/	31	/			61	/		
2	/			32		14		62		29	
3		1		33		15		63			/
4		2		34			/	64		30	
5			/	35	/			65	/		
6	/			36		16		66		31	
7		3		37			/	67			/
8		4		38	/			68	/		
9	/			39			/	69	/		
10			/	40		17		70			/
11		5		41	/			71		32	
12		6		42			/	72		33	
13	/			43		18		73	/		
14			/	44			/	74			/
15	/			45		19		75		34	
16		7		46		20		76			/
17		8		47		21		77		35	
18	/			48	/			78		36	
19	/			49		22		79			/
20			/	50			/	80			/
21		9		51		23					
22	/			52	/						
23			/	53		24					
24	/			54		25					
25		10		55			/				
26		11		56	/						
27		12		57		26					
28	/			58			/				
29			/	59		27					
30		13		60		28					

44 E
40 A
3 P

S. no 84 B used D of B 31.7.73 353.

Attributes Testing 4

1	T	V	X	O	25	T	V	X	O
2	X	O /	T	V	26	X	O	T	V
3	T	O/	X	V	27	T	O	X	V
4	X	V	T	O/	28	X	V	T	O
5	T	V	X	O √	29	T	V	X	O
6	X	f	T	V	30	X	O	T	V
7	T	g	X	V	31	T	O	X	V
8	X	V	T	g	32	X	V	T	O
9	T	V	X	F	33	T	V	X	O
10	X	O	T	V	34	X	O	T	V
11	T	O	X	V	35	T	O	X	V
12	X	V	T	O	36	X	V	T	O
13	T	V	X	O	37	T	V	X	O
14	X	O	T	V	38	X	O	T	V
15	T	O	X	V	39	T	O	X	V
16	X	V	T	O	40	X	V	T	O
17	T	V	X	O					
18	X	O	T	V					
19	T	O	X	V					
20	X	V	T	O					
21	T	V	X	O					
22	X	O	T	V					
23	T	O	X	V					
24	X	V	T	O					

0

APPENDIX 5

Reliability Study

Wisconsin Card Sorting Test

Reliability Study - Analysis of errors made on Wisconsin Card Sorting Test, using two sets of scoring criterion by both experimenter and co-scorer

The Wisconsin Card Scorting Test (Milner 1964) was administered to each subject on four occasions of equal intervals during a two year period. The experimental design, of which this task was a part, is fully described in Chapter 3, together with details of the task and its administration procedure.

The process of attainment of criterion for each attribute may be analysed as involving the formation of an hypothesis that e.g. colour is correct, and which is followed by the use of a strategy to test the hypothesis. Two kinds of strategy appear to be employed, first, a repetition of, or perseveration to, a previous hypothesis, or secondly, an alternation strategy, implying a change of hypothesis. Strategies may thus be considered to reflect the underlying hypotheses held by the children under study. Errors would therefore indicate a faulty hypothesis, or possible mismatch between the hypothesis and ability to test it, ie. limitations in information processing abilities (Weir 1964). Indeed, there is some evidence gained from notes of children's spontaneous comments that they were aware of their errors, but were unable to utilise them. This feature is considered in Chapter 5. Repetition of a response or perseveration to an incorrect hypothesis suggest that a child is unable to utilise errors by forming or testing a new hypothesis, eg. 'colour was not right, so try matching to shape', an example of an alternation strategy. The use of an alternation strategy suggests that the child can make sufficient use of an error to change hypothesis. A form of error analysis was therefore selected as an appropriate technique for determining strategy use. Each error was categorised as perseverative or alternating in relation to the immediately preceding response.

For all other tasks including pre-tests, categorisation could be made unambiguously, but in the task under consideration here, it was apparent early in the study, that there were a few responses which were less clearly categorised, and where the subject could have legitimately, although erroneously, have tested either of two hypotheses, ie. strategy use.

It was thus considered advisable to carry out an independent categorisation of errors to establish the inter-reliability of test-retest for both experimenter and co-scorer, and inter-reliability between experimenter and co-scorer using two sets of scoring criteria.

Method

A sub-sample of data was drawn by taking data on Wisconsin Card Sorting Test from 7 subjects at each of the three age groups (3 years, 5 years and 7 years at the commencement of the research). Data from a total of 21 subjects was thus obtained from each of the four test occasions, giving a total of 84 sets of scores, and these were considered to be a representative sample for a study of inter-scorer reliability on each of two sets of scoring criteria. Details of the criteria are included in this Appendix.

Photocopies of the 84 test record forms, with all indicators of the experimenter's categorisations removed, were given to a co-scorer for independent coding of error responses as perseverative or alternating. Training was given on the task administration by the experimenter, who also provided a set of criteria for coding responses. The independent categorisation to establish inter-scorer reliability took a total of twenty five hours, excluding the time spent in training. It included a cross-checking, by applying a logically equivalent, but different in detail, set of criteria for categorisation by both experimenter and co-scorer working independently. There were thus four separate scores for the test derived from all 84 sets of raw data (21 subject x 4 testings). These were entered into a matrix, yielding 6 correlation co-efficients for each age group, a total of 18, from the following four variables:

Variable 1	Experimenter's scores	1st set of criteria
Variable 2	Co-scorer's scores	1st set of criteria
Variable 3	Experimenter's scores	2nd set of criteria
Variable 4	Co-scorer's scores	2nd set of criteria

Inter-correlations were carried out of perseveration error scores yielded by each scorer applying each set of criteria, and summed across all four test occasions. Results (tables 89, 90, 91) indicate a high measure of agreement between experimenter and co-scorer on both sets of criteria. Correlation co-efficients are all statistically significant at $p < .01$ (N=84), with $r \geqslant .29$

Table 89 Correlation matrix for 3 year old sub-group between experimenter's and co-scorer's criteria and by experimenter and co-scorer.

Variable	1	2	3	4
1		.99	.98	.99
2			.98	.99
3				.99
4				

Table 90 Correlation matrix for 5 year old sub-group between experimenter's and co-scorer's criteria and by experimenter and co-scorer.

Variable	1	2	3	4
1		.98	.94	.90
2			.93	.92
3				.98
4				

Table 91 Correlation matrix for 7 year old sub-group between experimenter's and co-scorer's criteria and by experimenter and co-scorer.

Variable	1	2	3	4
1		.98	.94	.94
2			.95	.95
3				.96
4				

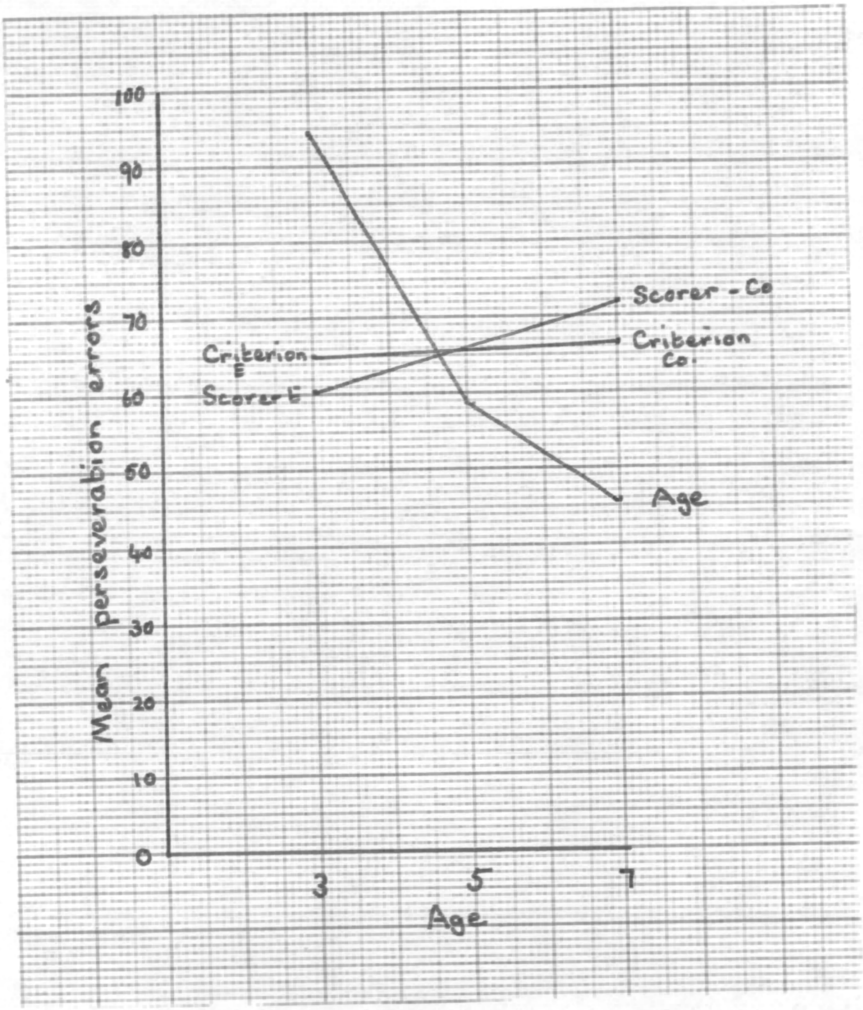
Following computation of correlation co-efficient, a three-way Analysis of Variance was carried out to test for significant differences between mean perseveration error scores, obtained from application of experimenter's and co-scorer's criteria, by both experimenter and co-scorer, (used as the dependent variable. The design selected was mixed, with one between (age) and two within (criteria and scorers) factors, where cells have equal numbers. Computation was carried out, using the programme developed by Versey (1983) for Apple.

Table 92 Three-Way Analysis of Variance - Repeated Measures on Perseveration errors scored by experimenter & Co-Scorer using both sets of criteria.

Source	S.S.	d.f.	M.S.	F	Sig. level
Between	66310.67	20			
Age	35702.95	2	17851.48	10.5	.01
Error	30607.71	18	1700.43		
Within					
Criterion	3060.11	1	3060.11	98.21	.001
AgexCriterion	52.29	2	26.14	.84	
Error-Criterion	560.85	18	31.16		
Scorer	38.68	1	38.68	6.47	.05
AgexScorer	14	2	7.00	1.17	
Error-Scorer	107.57	18	5.98		
CriterionxScorer	16.3	1	16.3	6.87	.05
AgexCriterionxScorer	77.24	2	38.62	16.27	.001
Error-CriterionxScorer	42.72	18	2.37		

Table 92 shows statistically significant differences between means for age groups, as is predicted from the aims of the study. However, significant differences are shown for scores obtained by the use of the tw sets of criteria, and by the scorers. There are additionally, statistically significant interactions between criteria and sc r rs, and between age, criterion and scorer. Means for the three-way interaction are plotted as Figure 33 . The graph suggests that the interaction of criterion and scorer with age is most pronounced at the 5 year old level. The implication is that, at this age-level, there is more ambiguity about the hypothesis being tested, and therefore, the strategy used.

Figure 33 Three-way interaction between Age, Criterion and Scorer. Wisconsin Card Sorting Test - Reliability Study.



Implications for the Research

Inspection of Figure 33, which was plotted following Analysis of Variance, shows that mean perseveration errors scored by the experimenter are less than those scored by the co-scorer, on both sets of criteria. Application of the second criterion (co-scorer's) would raise each child's perseveration error score, and thus give the child less credit for the use of the more advanced strategy, alternation. Since one of the research questions concerns task-variables in strategy use, it is considered important to avoid biassing results through artificially raising perseveration error scores.

The decision has therefore been made in the light of these results, together with the added support from the statistically highly significant reliability co-efficients, to retain the first set of criteria for scoring this task. The correlation analysis yielded co-efficients of two aspects of reliability. These are, first, the experimenter's test-retest reliability, and separately, the co-scorer's, scorings on both sets of criteria (variables 1 and 3 , 2 and 4), and secondly, an inter-scorer reliability between experimenter and co-scorer, again on both sets or criteria (variables 1 and 2, 1 and 4, 2 and 3, 3 and 4). Correlation co-efficients are consistently high, indicating a substantial degree of reliability which is independent of scorer or set of criteria.

Further support for the criterion for scoring, adopted as a result of this study, is given by its consistency with that used in analysing the other experimental tasks. It is further suggested that the method defined by the first set of criteria is an appropriate one for use in further studies of children's strategy availability and use. Although the issue of unambiguous categorisation of responses, which led to the decision to carry out this reliability study, is likely to be faced by other researchers, since it is inherent in the task itself, it does not appear to have been discussed even in current research. Particularly where the task is used in studies of behavioural effects of frontal lobe damage in children (Vargha-Khadem 1983) or for its original use with adults eg. Milner (1964), it would seem important to categorise errors as accurately as possible. As the review of the literature indicates, the exact nature of cognitive deficit arising from frontal lobe damage has proved elusive.

Assumptions made in scoring errors - Wisconsin Card Sorting Test

Criterion 1 - Experimenters

1. First error of new category where this is repetition of previously correct category = perseveration
2. Switch from previous correct response = alternation
3. Switch from one category to another = alternation
4. Repetition of previous incorrect position response = perseveration
5. Repetition of previous incorrect category = perseveration

Criterion 2 - Co-scorers

The assumptions listed under criterion 1 were accepted but where a response could be attributed to two possible incorrect hypotheses, criterion 2 interpreted the error as perseveration to the previously correct category. Less regard was paid to position.

Comment

Coding based on behavioural evidence was deemed methodologically more appropriate (criterion 1), than to make inferences concerning a child's intention (criterion 2).

APPENDIX 6

Schools used - Pilot Study

Main Study

Schools

Pilot Study

Trotts Hill Infant School, Stevenage, Herts. (now Trotts Hill J.M.I. School).

Main Study

Playgroups	L.S.E.S.	St Judes Play-group, Islington, London N1 Highbury Quadrant Play-group, Islington, London N1
	U.S.E.S.	Budleigh Play-group, Ongar, Essex
Schools	L.S.E.S.	Argyll Primary School, Camden, London WC1 Highbury Quadrant JMI School, Islington, London N1 St. Judes JMI School, Islington, London N1 Vittoria Primary School, Islington, London N1
	U.S.E.S.	Chipping Ongar Junior School, Ongar Essex Chipping Ongar Infant School, Ongar Essex St. Thomas of Canterbury Junior School, Brentwood, Essex St. Thomas of Canterbury Infant School, Brentwood, Essex

Additional schools used after 5 playgroup children transferred as individuals to reception or under-fives classes in other than main schools listed above:

L.S.E.S.	St Joan of Arc R.C. Primary School
U.S.E.S.	Moreton Primary School, Moreton, Essex P.N.E.U School, Stondon Massey, Essex

APPENDIX 7

COPY - DEVELOPMENTAL CHANGES IN CHILDREN'S MODES OF REPRESENTATION USED BETWEEN 3 AND 9 YEARS

Clayfield, R.G. and Davis, T.N.

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Develop~~ental Cł anges in Children's Modes of P~~esent~tion used between 3 and 9 Years

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Introduction

Evidence for the mature and interchangeable ability to utilise action patterns, image and language as means of problem-solving comes primarily from adult introspection. Adults possess the metacognitive ability to inspect their own thinking processes, and be aware that, for example, if asked the way to a tube station by a visitor new to a town, they could lead that visitor to the tube station, or visualise the journey whilst attempting to give directions. These are reconstructional processes. When time and goodwill permit, it is often simpler to activate the series of motor patterns which lead to the desired destination; the giving of verbal directions or drawing of a plan may be confused by difficulty in rer ~bering whether the correct path is the second or third turning on the left. Even in the adult, action patterns may be primary, although, as ıner points out, at the instructional level, language can conjure image and appropriate action. At what point the mature abilities become established in children is unclear, although ikonic and symbolic modes of mental representational ability can be inferred from the many studies of, for example, Inhelder and Piaget (1964) or Bruner (1966) amongst others. In the study reported here, an attempt was made to identify these levels of problem-solving ability through an experiment using the Oddity problem.

The Oddity Problem

The Oddity Problem was used by H Harlow (1949) in comparative studies of formation of learning sets in children and monkeys. He defined a learning set as the acquisition of an organised set of habits that enables effective solution of new problems of a similar kind. In an oddity problem, 2 identical and one odd stimuli are used, and the task is to respond accurately to the odd one on each trial. To do this, the subject must ignore the particular stimulus array, including position of the odd member, and inhibit tendency to perseverate or alternate responses. Reversal learning is a necessary consequence, and one which illustrates a phylogenetic trend. Although monkeys perform better than young children in trial and error learning of a problem using 24 trials, children subsequently perform better than monkeys in reversing the response to one problem in order to solve the next. Piaget, too, has presented children with an oddity problem, but termed it the concept of the singular class. Representational ability, manifested by the ability to define the concept, was found not to be fully established until around 10 years of age. This was similar to the findings by Lunzer and Aston in a study reported in The Regulation of Behaviour (1968), in which they used 20 problems of 6 trials each on 6 children at each age from 4 to 10 years. This was followed by 5 problems of 1 trial each (generalisation), and subsequently by 5 trials in which the subject was asked to set the experimenter similar problems for solution. The final stage was to ask for a verbal justification of the solution rule. Using a total of 120 trials, only one child at age 4 failed to learn the first stage of the problem, but not until age 8 could most children give a satisfactory verbal explanation, or pose similar problems. The results were interpreted as evidence of a growing mental representational ability.

The Present Experiment

The present study extends the investigation to a larger sample of children, including three year olds, and to seek direct empirical evidence for the developmental emergence of enactive, ikonic and symbolic modes of representation. The procedure used by Lunzer and Aston was replicated with some modifications. These were, first, the number of trials used in the initial discrimination learning stage (stage 1) where, instead of 20 problems of 6 trials each, 10 problems were used. This was deemed methodologically sounder since 3 year olds were also to be the subjects of study. Even with older children, boredom and fatigue factors need to be considered. For the same reason, one trial only was given for the fourth stage in which the experimenter asked the subject to set a similar problem, and which all subjects who solved the discrimination and generalisation of stages, were asked to do, irrespective of performance on the verbal justification question. The ability to set a similar problem is considered to provide inferential evidence that an ikonic mode of representation is available to the child, and the hypothesis tested is that there is a developmental order of emergence of the three modes of representative and therefore the ability to image precedes the metacognitive ability to reflect upon action in the symbolic mode of language.

Ninety six children aged 3 years (n = 32, $\bar{x}$ age = 3.2 years), 5 years, (n = 32, $\bar{x}$ age = 5.2 years) and 7 years (n = 32, $\bar{x}$ age 7.3 years) drawn equally from upper and lower socio-economic groups, and with equal numbers of boys and girls in each age group, formed the subjects of this study. They were tested on the Oddity Problem on 4 separate occasions of equal intervals of 7-8 months during a 2 year period. The groups were thus aged 5, 7 and 9 years at the conclusion of the study.

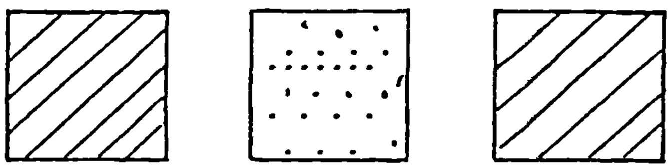
Testing was carried out individually in the playgroup or school attended by the children. As would be expected, the children moved upwards through the school system during the 2 year period of study, and most transferred to new classes or schools. In all cases, with the cooperation of the Heads and classteachers, the children were followed up in their new environment.

Procedure

Materials

Set of coloured 4 cm sq. cards, 2 each of green, light blue, red, orange, green, yellow, purple, black, dark blue, ochre.

Presented as, e.g.



centre as odd example in this

For each problem a fresh selection was made of 2 identically coloured cards and one odd one. The position of the odd one is counterbalanced across trials, in predetermined order which was the same for all subjects. A marble was given for each correct choice, and cashed at the end for some Smarties. There were 2 criteria for initial solution: (1) not more than 3 errors in 18 preceding trials (discrimination learning), (2) errorless solutions on 5 x 1 trial problems (generalisation).

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"I want you to choose a card" - point to cards
"If you choose the right one, I will give you a marble. Try to be right every time."

No other instruction was given, except that for every failure after trial 30 a hint is given "There is a trick to get it every time." (this instruction was used by Lunzer and Aston).

Third stage - the subject was asked "How did you know which one to choose?"

Fourth stage - the subject was asked "Could you make a puzzle for me to do that is just like the one you have done?"

S was then required to set an oddity problem for the experimenter to solve.

<u>Results</u>

Responses were categorised for each of the levels of solution, discrimination learning (DIS), generalisation to new problems (GEN), ability to set the experimenter a similar problem (IM), and ability to give a verbal justification (VJ).

Data was thus obtained in a nominal form for each of the 4 test occasions.

Table 1 shows the raw number of passes at each level of solution for each age group.

TABLE 1 Raw numbers of passes at each level of Solution by year groups

	Testing 1 DIS	GEN	IM	VJ	Testing 2 DIS	GEN	IM	VJ	Testing 3 DIS	GEN	IM	VJ	Testing 4 DIS	GEN	IM	VJ
3-5 years (N = 32)	3	0	0	0	7	2	1	0	13	6	5	3	24	11	10	8
5-7 years (N = 32)	22	18	15	10	25	21	15	13	31	25	22	21	32	29	28	21
7-9 years (N = 32)	26	24	23	20	29	28	25	26	32	31	30	28	31	29	29	29

TABLE 2 Raw numbers of passes at each level of Solution by Sexes

		Testing 1 DIS	GEN	IM	VJ	Testing 2 DIS	GEN	IM	VJ	Testing 3 DIS	GEN	IM	VJ	Testing 4 DIS	GEN	IM	VJ
3-5 yrs	Boys	1	0	0	0	2	1	1	0	5	2	2	1	11	3	3	2
	Girls	2	0	0	0	5	1	0	0	8	4	3	2	13	8	7	6
5-7 yrs	Boys	8	7	6	4	12	9	8	5	16	12	10	10	16	14	13	10
	Girls	14	11	9	6	13	12	7	8	15	13	12	11	16	15	15	11
7-9 yrs	Boys	13	12	12	11	16	16	15	16	16	16	16	15	15	14	14	14
	Girls	13	12	11	9	13	12	10	10	16	15	14	13	16	15	15	15

TABLE 3 Raw numbers of passes at each level of Solution by Socio-Economic Grouping

		Testing 1 DIS	GEN	IM	VJ	Testing 2 DIS	GEN	IM	VJ	Testing 3 DIS	GEN	IM	VJ	Testing 4 DIS	GEN	IM	VJ
3-5 yrs	Uses	2	0	0	0	5	2	1	0	11	6	4	3	13	7	5	6
	Lses	1	0	0	0	2	0	0	0	2	0	1	0	11	4	5	2
5-7 yrs	Uses	12	10	8	6	14	12	9	8	16	13	11	11	16	15	15	13
	Lses	10	8	7	4	11	9	6	5	15	12	11	10	16	14	13	8
7-9 yrs	Uses	13	11	11	10	14	13	10	12	16	15	14	14	16	15	15	15
	Lses	13	13	12	10	15	15	15	14	16	16	16	14	15	14	14	14

Passes at each level of solution (DIS, GEN, IM, and VJ) were analysed by the Cochran Q test for each age level, and for each testing. Significant differences were shown for each testing for the 3 - 5 year and 5 - 7 year age groups (Table 2).

TABLE 4

Q values for significant differences between levels of solution for each test occasion (Cochran Q test)

	Testing 1		Testing 2		Testing 3		Testing 4	
	Q	$p<$	Q	$p<$	Q	$p<$	Q	$p<$
3-5 years	9.0	.05	15.8	.001	20.6	.001	35.9	.001
5-7 years	22.4	.001	23.7	.001	18.0	.001	21.6	.001
7-9 years	11.8	.01	6.6	n.s	8.0	.05	6.0	n.s

For the 7 - 9 year age group, significant differences were shown at the first and third testings but were non-significant for the second and fourth. This would suggest that in the eighth and ninth years the children were in the main, able to use enactive (DIS and GEN), ikonic (IM), and symbolic (VJ) modes of representation when necessary for problem solution.

For more detailed analysis, the McNemar test for the significance of changes was applied to all possible pairs of solution levels across testing, so that, for instance DIS Testing 1 was compared with DIS Testing 2, DIS(2) with DIS(3) and DIS(3) with DIS(4). Significant differences were shown for the 3-5 year old group on the comparison between DIS(3) and DIS(4), $\chi^2 = 5.8$ $p < .01$, and this would suggest a marked increase in the ability to solve the discriminatior learning stage of the Oddity Problem in the second half of the fifth year. Similarly, a marked change occurred between the second and third testing for the 5 - 7 year old age group in the ability to image, as demonstrated by setting the experimenter an Oddity Problem. Significance testing was made by Binomial Test ($p < .05$) in view of the small expected frequencies.

Sex Differences

The data was further analysed to indicate whether there were differences between sexes in ability to solve the four levels of Oddity Problem. For the 3 - 5 year old group, whilst there were tendencies for girls to give superior performances on each of the four testings, these did not reach significance levels. At 5 years, girls were significantly better than boys in learning the first level (DIS) of the problem ($X^2 = 5.24$ $p < .05$) for test 1. It would appear that there are sex differences and some evidence for differential rates of development, and for these to be demonstrated at the optimal period of 5 - 7 years. A ceiling effect across the tests for the age of 8 + obviates further evidence of sex differences. Boys in the 7 - 9 year group were superior on the second testing, i.e. mean age 7.9 at learning the generalisation (GEN) ($X^2 = 5.57$ $p < .05$), imagery (IM) ($X^2 = 4.57$ $p < .05$), and verbal justification (VJ) ($X^2 = 7.38$ $p < .01$) stages of the Oddity Problem.

Socio-exonomic Status

Analysis using Cochran Q test indicated a more rapid rate of development in levels of solution within testings for the upper socio-economic status sub-group of 3-5 group at the second and third testing. Whereas significant results were obtained for the upper socio-economic group (USES , $Q = 10.0$ $p < .01$, this was not the case for the lower socio-economic group (LSES).

X^2 tests were applied to the data to investigate whether there were differences between socio-economic groups in ability to solve the four levels of Oddity Problem. Upper socio-economic groups were statistically superior at the third testing of 3-5 year old group on the discrimination learning and ability to generalise to new problems. ($X^2 = 8.29$ $p < .01$ DJS, $X^2 = 5.13$ $p < .05$ GEN), with Yates correction. For the 5-7 year old groups, no significant differences were shown, although a consistent trend was observed in favour of USES group but for the 7-9 group, the trend was no longer observable. However, as with sex differences, ceiling effects at older levels militate against the possibility of significant differences between socio-economic groups.

Discussion

The results indicate that there is a developmental trend in achieving the 4 levels of solution in the Oddity Problem. With only 5 exceptions out of the total sample of 96 children, all subjects who solved the discrimination and generalisation stages of the problem were able to image, as defined by ability to set the experimenter an Oddity Problem, in advance of being able to give a verbal justification. Of the 5 exceptions, four were girls, and four were from the USES group. All were regarded as bright by their respective teachers. The 3 year old began reading before infant school entry, and the older children were able to enjoy lengthy children's fiction books. Their superiority on the verbal justification level of solution over the ability to image raises questions of whether, for those children, the ikonic mode was not well developed or whether encoding in language had become a preferred mode of functioning. It is possible, too, that as functional use of language develops, imaging ability atrophies, perhaps analogous to the developmental anomaly of decline in eidetic imagery. Although these children were exceptions, the issue is raised concerning the matching of the curriculum in order to capitalise on strengths, or whether the ability to reconstruct experience (image) is a necessary aspect of becoming educated, and which has therefore different implications for an individual child's curriculum. The nature of an image is an unresolved issue. Bruner has used it somewhat eclectically, although his writing makes clear (1966) that he was aware of the ambiguity. In the sense in which it has been used in this paper, 'image' has been defined as a reconstruction of experience, rather than as a template. (Pylyshyn 1973). Nevertheless, as Bruner has suggested, it would appear that the emergence of this ability follows as a disembedding from immediate action, and precedes the ability to use language to reflect on experience. In part, Bruner has drawn on work carried out in Luria's laboratory to support his argument. Luria (1961) cited experiments by Abramyan and Martsinovskaya using aeroplanes on coloured grounds to test development of verbal regulation of behaviour. This experimental variation may induce imaging and thus support the child's emerging regulatory behaviour. This would seem to have implications for the education of nursery, infant and younger junior school children. In particular, it is suggested that since the evidence from the present experience supports the hypothesis that use of image precedes use of language, then the curriculum should reflect this. However, the five exceptions who were verbally more successful, lead to the conclusion that some choice for children is desirable. In practical terms, children might be allowed to exercise individual discretion over whether, at infant and young junior school ages, drawing of a picture precedes or follows talk or writing about experiences; in practice a variety of learning styles should be allowed for in the organisation of the curriculum.

One further point is of educational relevance. Inspection of raw scores shows that for 7-9 year old group, the number of successes on DIS, GEN, and IM is fewer at Testing 4 than at Testing 3. This is substantially accounted for by one boy from the lower socio-economic status group (see Table 2), who lost much of the sight in one eye during a summer holiday accident when street play led to a sharp object piercing the eye. From total success at Testing 3 he was, at Testing 4, only able to solve the DIS level of the Oddity Problem. The accident was not noted in the class - teachers or school records, although its effects were known. The probability exists, that, with reduced vision which led to regression in performance, this will have implications for reading development, and for the increasingly fine differentiations to be made in, for instance, scientific work in the school years. It is suggested that scrupulous record-keeping which includes significant life events, would enable teachers to identify children with late-occurring special educational needs. (Warnock 1978).

Further research is needed into how far the development of modes of representation can be facilitated by practice. The early advantage of USES groups over LSES does not appear to have been maintained, in part due to ceiling effects of the test, but there is some evidence that entry into the education system has potential for narrowing the gap between social class groups rather than widening it, as in generally thought to be the case. It may be that higher modes of function can be accelerated through appropriate curricula, particularly since early differences are also likely to be related to differential experiences. There is some evidence of practice effects which add support to this point.

A point of current interest is the lack of differences in performance by girls over boys by ages 7-9, although girls had some advantage at the younger ages. The early advantage of girls is consistent with other aspects of development, but leaves unanswered the vexed question of how far biological and social variables account for this.

The experiment presented in this paper was designed to test the hypothesis that there is a developmental order in emergence of modes of representation. Results would indicate support for the hypothesis, and therefore for some aspects of Bruner's Theory of Instruction. An additional question of considerable interest, concerns the point at which interchangeability between modes of representation becomes established, and further research is required.

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